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Mapping Farmers' Preferences for Climate Change Adaptation Measures: Stated Preference and Field Experiments in Ethiopia

Kartlegging av småbønders preferanser for klimatilpasningstiltak: Uttrykte preferanser og eksperimentelle studier i Etiopia

Abrha Megos Meressa

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Contents

List of Papers

This thesis consists four papers.

Paper I

Exploring Farmers' Technology Preference under Hard Uncertainty: Experimenting on Reference Point and Learning

Co-author: Ståle Navrud

Paper II

Do Farmers in Developing Countries Value River Ecosystem Services improvements? A Choice Experiment of Ethiopian Farmers´ Adoption of Sustainable Management Strategies.

Co-author: Ståle Navrud

Paper III

Not my Cup of Coffee:

Trait Preferences of Farmers for Coffee Variety – Lessons for Crop Breeding in the Age of Climate Change

Co-author: Ståle Navrud

Paper IV

How does Climate Change Skepticism affect Preferences for Forest Conservation in Developing Countries?

Summary

This thesis maps preferences for climate change adaptation measures and ecosystem services among Ethiopian smallholder farmers; by analyzing their decision-making behavior under uncertainty in a framed field experiment, their stated preferences for ecosystem services, and factors motivating and constraining their preferences for these services and adaptation measures. More specifically, the four papers of the thesis address the following research questions. (i) What decision criteria do farmers use to make choices under hard uncertainty?; (ii) Do smallholder farmers in developing countries value river ecosystem services improvements?; (iii) Which traits of coffee varieties do farmers prefer the most to cultivate in the age of climate change?; and (iv) How does climate change skepticism affect farmers´ preferences for forest conservation in developing countries?

The first paper uses a framed field experiment with real payments to test whether smallholder farmers adapt criteria that minimize loss in crop yield (i.e. the minimax criterion), minimize the maximum opportunity loss (i.e. minimax regret criterion), or maximize expected value (i.e. the expected value maximizing criterion) when choosing between prospects under hard uncertainty. The experiment tested two different payment options. The first group of participants received their payment in cash only. The participants in the second group could choose between cash and in-kind payment (which was a shovel) if their aggregate payment at the end of the experiment reached or surpassed the threshold limit of 90 Ethiopian Birr, ETB (equivalent to two days´ wages). Otherwise, they received their payments in cash only. The final payment they received depended on their actual choices between three prospects in a total of five rounds. Prospect theory states that people evaluate outcomes relative to a reference point (threshold), and that this influences their loss aversion. Results showed that choices under uncertainty are not arbitrary. Most farmers in both payment treatments made choices that minimize losses during the first round when uncertainty was high as they had no or little experience with the choice tasks. However, a larger share of the farmers that could choose between cash or in-kind payments if they passed the threshold continued making choices that minimized losses throughout the experiment. This indicates that farmers minimize losses without considering the costs of making wrong choices (which would be the maximum regret criterion) or maximize the

expected values, when there is a threshold for having the choice between in-kind and cash payments and the uncertainty is relatively high. Farmers with at least secondary education, or having more experience from choices in the earlier rounds, tend to make more choices that minimize the maximum regret and/or maximize the expected value outcomes. However, repeated losses increase loss aversion in later rounds, and hence choices that minimize losses.

The second paper discusses the nature of farmers' preference for river ecosystem service (ES) improvements, and examines the role of provisioning services in explaining preference heterogeneity. We specify four river ES attributes: i) water supply reliability, ii) flood protection, iii) riparian vegetation, and iv) water quality; and conduct choice experiments among farmers in northern Ethiopia. We find that farmers have strong preferences for improving all the river ES attributes, and strongest for those attributes that increase the provisioning ES of their agricultural yield. Farmers exhibit preferences heterogeneity for the river ES attributes in terms of: i) Farmers with access to irrigable land are willing to pay more for water supply improvement, ii) those engaged in beekeeping are willing to pay more for riparian vegetation, and iii) farmers with plots further away from the rivers are willing to pay less for flood protection services. Mean willingness-to-pay (WTP) estimates show that farmers have stronger preference for the improvement of flood protection services than for the other river ES. This is in agreement with the high degree of loss aversion observed in the first paper.

The third paper reports farmers´ preferences for genetic traits of coffee varieties using choice experiments, and presents evidence that farmers have stronger preferences for yield stability traits such as disease resistance and weather tolerance than for high yielding traits or early maturing traits. This implies that farmers give priority to coffee traits that ensure stable yield rather than maximum yield in the face of environmental and weather stressors. Thus, despite the successful efforts of crop breeding programs to deliver yield improving coffee varieties, farmers' adoption of high yielding varieties remains less than desirable. Therefore, understanding farmers' preferences for coffee traits is important in order to develop new, improved coffee varieties that farmers demand and adopt, and increase their yield. It also implies that *in-situ* conservation of the coffee genetic diversity should be

complemented by *ex-situ*– conservation, in order to preserve coffee varieties with traits that farmers prefer less to cultivate and maintain in their fields. Just like in papers 1 and 2, we see that Ethiopian farmers exhibit a high level of loss aversion when choosing among climate change adaptation strategies.

The fourth paper examines how environmental and climate change skepticism attitudes affect farmers´ preferences for increased forest conservation. The results reveal that high levels of environmental skepticism, such as believing that God causes climate change and that climate change discussions in the media are exaggerated. Environmental skepticism significantly reduce farmers´ likelihood of paying for forest conservation. Farmers recognizing the contribution of forests to mitigating climate change, and those that recognize the long-term benefits of adaptation measures over present gains of not adapting, on the contrary have a higher likelihood of paying for forest conservation, and have a higher mean WTP than the others. Farmers´ likelihood of being willing to pay for forest conservation programs also increase significantly with higher levels of education and awareness of deforestation, which are also connected to a lower level of environmental skepticism. Thus, education and awareness raising activities are important in order to reduce environmental skepticism and increase forest conservation as a climate change mitigation measure.

Overall, the four papers present evidence for a high level of loss aversion among Ethiopian smallholder farmers under climate change uncertainty. Farmers reveal stronger preferences for flood protections measures and stable yield coffee varieties such as weather tolerant and disease resistant traits, and make choices that minimize losses under uncertainty. Farmers also have significant and positive preferences for preserving river ecosystem services and forests. Thus, with targeted measures reducing the risk of losses and promoting sustainable adaptation measures, smallholder farmers can be both the main custodians and beneficiaries of ecosystem services conservation in terms of increasing their long-run ability to adapt to climate change. This can contribute towards the Ethiopia´s endeavor to achieve the ambition of building a climate resilient green economy.

Sammendrag

Denne avhandlingen kartlegger preferansene for klimatilpasningstiltak og økosystemtjenester blant småbønder I Etiopia. Deres beslutningsadferd under usikkerhet i et økonomisk felteksperiment analyseres, samt deres uttrykte preferanser for økosystemtjenester og faktorer som motiverer og begrenser deres preferanser for disse tjenestene og klimatilpasningstiltak. Mer spesifikt søker avhandlingens fire artikler å svare på følgende forskningsspørsmål: (i) Hvilke beslutningskriterier bruker småbønder for å gjøre valg under usikkerhet når sannsynlighetene for utfallene ikke er kjent?, (ii) Verdsetter småbønder i utviklingsland økosystemtjenester ved vassdrag? (iii) Hvilke egenskaper hos kaffevarieteter foretrekker småbøndene å dyrke i klimaendringenes tid?, og (iv) Hvordan påvirker klimaskepsis småbønders´ preferanser for skogvern i utviklingsland?

Den første artikkelen bruker et økonomisk felteksperiment med faktisk betaling for å teste hvorvidt bønder bruker kriterier som minimerer avlingstap (dvs. minimaks kriteriet), minimerer det største tapet (dvs. minimaks-angre kriteriet), eller maksimere forventningsverdi (dvs. maksimum forventningsverdi kriteriet) når de velger mellom ulike kombinasjoner av utfall under usikkerhet, uten å vite sannsynlighetene for utfallene. Eksperimentet testet to ulike utbetalingsmåter. Den første gruppen av deltagere mottok betaling kun i kontanter. Deltagerne i den andre gruppen kunne velge mellom å motta betaling i kontanter eller i form av en spade dersom utbetalingene deres på slutten av eksperimentet var over en nedre grense på 90 etiopiske birr, ETB (som tilsvarer lønn for to dagers arbeid). Hvis ikke, fikk de utbetalingen i kontanter. Sluttutbetalingen de mottok avhang av deres faktiske valg mellom tre kombinasjoner av utfall i totalt fem runder. Prospektteorien sier at folk vurderer utfall relativt til et referansepunkt (grense), og at det påvirker deres tapsaversjon. Resultatene viste at småbøndenes valg under usikkerhet ikke er vilkårlige. De fleste bønder i begge underutvalg foretok valg som minimerer tapene i de første rundene da usikkerheten var stor og de hadde ingen eller liten erfaring med valgoppgavene. En større andel av bøndene som kunne velge mellom kontanter og spaden om de passerte den nedre grensen fortsatte imidlertid med å gjøre valg som minimerte deres tap gjennom hele eksperimentet. Dette indikerer at bøndene minimerer tapene uten å

vurdere kostnadene ved å gjøre feil valg eller uten å prøve å maksimere forventningsverdiene, når det er en nedre grense for å få valget mellom utbetaling i kontanter eller som en spade og usikkerheten er relativt høy. Bønder med utdannelse utover grunnskolen, eller som har mer erfaring fra valg i tidligere runder av eksperimentet, synes å gjøre flere valg som minimerer det maksimale tapet og/eller maksimerer forventningsverdien av utfallene. Gjentatte tap øker imidlertid tapsaversjon i senere runder, and således valg som minimerer tap.

Den andre artikkelen diskuterer bønders preferanser for forbedringer i økosystemtjenester (ØT) ved elver, og undersøker hvilken rolle forsyningstjenester har i å forklare heterogenitet i preferansene. Vi spesifiserer fire ØT atributter: i) pålitelighet i vannforsyningen, ii) flomvern, iii) vegetasjon langs elvebredden, og iv) vannkvalitetsforbedringer; og gjennomfører et valgeksperiment blant småbønder i Etiopia. Vi finner at bøndene har sterke preferanser for å forbedre alle ØT ved elver, og sterkest for de attributter som øker forsyningstjenesten i form av deres egne avlinger. Bøndene viser heterogenitet i sine preferanser for ØT i elvene i form av: i) Bønder med tilgang til land som kan vannes kunstig er villig til å betale mer for bedret vannforsyning, ii) de som driver med birøkt er villig til å betale mer for mer vegetasjon langs elvebredden, og iii) bønder med jorder lenger vekk fra elven er villig til å betale mindre for forbedret flomvern. Dette er i tråd med den høye grad av tapsaversjon som ble observert i den første artikkelen.

Den tredje artikkelen rapporterer om bønders preferanser for genegenskaper blant kaffevarieteter, og finner bevis for at bøndene har sterkere preferanser for avlingsstabiliserende egenskaper slik som sykdomsresistens og værtoleranse enn for egenskaper som gir store avlinger og tidligere modning. Dette betyr at bøndene prioriterer kaffeegenskaper som gir stabil avling heller enn maksimal avling når de konfronteres med miljø- og værmessige stressfaktorer. Så til tross for vellykkede avlsprogrammer som leverer varieteter av kaffe som gir store avlinger, er småbønders anvendelse av disse mindre enn det som er ønsket. Derfor er det viktig å forstå småbønders preferanser for egenskaper ved kaffe slik at det kan utvikles nye, forbedrede varieteter som de etterspør og vil anvende slik at deres avlinger øker. Det innebærer også at *in-situ* bevaring av kaffens genetiske diversitet bør komplementeres med *ex-situ* bevaring, for å bevare kaffe varieteter med egenskaper som

bøndene i mindre grad foretrekker å plante og opprettholde på markene sine. På samme måte som i artikkel 1 og 2, ser vi at etiopiske bønder har en høy grad av tapsaversjon når de velger mellom klimatilpasningsstrategier.

Den fjerde artikkelen undersøker hvordan miljø- og klimaskepsis påvirker bønders preferanser for økt skogbevaring. Resultatene avslører en stor grad av klimaskepsis, slik som at Gud forårsaker klimaendringer og at påstander om klimaendringer i media er overdrevet Miljø- og klimaskepsis medfører en signifikant reduksjon i bøndenes sannsynlighet for å betale for skogbevaring. Bøndene som erkjenner skogens bidrag til å redusere klimaendringer, og de som erkjenner de langsiktige nyttevirkninger av klimatilpasningstiltak framfor kortsiktig vinning av ikke å tilpasse seg, har derimot en høyere sannsynlighet for å betale for skogbevaring, og høyere gjennomsnittlig betalingsvillighet enn andre. Bøndenes sannsynlighet for å betale for skogbevaringsprogammer øker også signifikant med høyere utdanningsnivå og høyere oppmerksomet omkring avskoging, som også er forbundet med lavere nivå av miljø- og klimaskepsis. Det betyr at økt utdanning og aktiviteter som gir økt oppmerksomhet omkring avskoging er viktige for å redusere miljø- og klimaskepsis og øke skogbevaring som et klimatiltak.

Samlet sett gir de fire artiklene bevis for et høyt nivå av tapsaversjon blant småbønder i Etiopia ved klimaindusert usikkerhet. Bøndene viser sterke preferanser for flomvern og genetiske egenskaper ved kaffe som gir stabile avlinger, slik som værtoleranse og sykdomsresistens, og foretar valg som minimerer tap under usikkerhet. Bøndene har også signifikante og positive preferanser for å bevare økosystemtjenester av elver og skog. Med tilpassede tiltak som reduserer risiko for avlingstap og promoterer bærekraftige tilpasningstiltak, kan småbønder være de som i hovedsak forvalter og drar nytte av økosystemtjenestene ved å øke deres evne til å tilpasse seg klimaendringer på lang sikt. Det kan bidra til Etiopias bestrebelser på å oppnå ambisjonen om å bygge en klimabestandig, grønn økonomi.

Mapping Farmers' Preferences for Climate Change Adaptation Measures: Stated Preference and Field Experiments Evidence

1. Introduction

Climate change adaptation is an adjustment in economic decisions by an individual or by a community of individuals in an effort to cope with changes in the climate regime. In the low-latitude developing countries regions with poor adaptive capacity, where small changes in temperature can bring substantial adverse consequences, adapting to climate change is inevitable and particularly urgent for the farmers and natural resource managers (Mendelsohn, 2012). Global average temperature has risen over the years (Hansen*, et al.*, 2006), and it imposes challenges not only to ecosystems but to societies as well. In the extreme case, the risk involved with climate change is undefined (Mandelbrot & Hudson, 2004; Weitzman, 2009). As a result, the role of climate change adaptation has received increasing attention, but farmers' preferences of adaptation measures and factors motivating their adaptation behavior are still poorly understood (see Below*, et al.*, 2012).

Mapping smallholder farmers' preferences for adaptation measures and factors influencing their adaptation behavior can help to define well-targeted adaptation measures and adequately integrate them into development and climate change mitigation programs that reduce the climate change and its consequences. IPCC (2007) reports that adaptive capacity is linked to social and economic development, and thus even a relatively small climatic shift in developing countries can trigger or exacerbate food insecurity, water scarcity and deforestation. This affirms the consensus on the need to improve adaptive capacity to the changing climate conditions in developing countries. Use of agricultural technology, improved varieties, rehabilitation of rivers for irrigation and forest conservation are among the adaptation options to reduce the adverse impact of climate change on the environment and human wellbeing. Understanding whether farmers prioritize maximizing value, or minimizing loss or minimizing the maximum opportunity loss (regret), when they make technology adaption decisions under circumstances that involve risk and uncertainty, and

mapping their preferences of adaptation measures is essential to be able to institutionalize and integrate adaptation polices with development programs in developing countries. Identifying climate-change adaptation options farmers chose or/and do not choose, and distinguishing the attributes of the adaptation options that the farmers chose and/or do not choose is also important for modeling their choices for adaptation measures.

Therefore, this thesis attempts to answer important questions in four separate papers. The first question of the thesis concerns the decision-making behavior of farmers under uncertain circumstances; i.e. whether they consistently minimize loss (use minimax criterion), minimize maximum regret (use minimax regret criterion) or maximize gain (use maximum expected value criterion) under different contexts. Risk associated with climate change and technology adoption is not known in advance, and thus is rather hard uncertainty. In the first paper of the thesis, "Exploring farmers' technology preferences under hard uncertainty", we conducted framed field experiment on Ethiopian farmers, randomly assigning farmers into two groups: farmers in the first group receive their payment only in cash, and the farmers in the second group can choose their payments to be either in cash or in-kind, if they pass a threshold limit. In this paper, we found evidence that farmers do not make consistent use of one decision criterion. More farmers make choices that minimize loss under the in-kind/cash optional payment with a reference point than under the cash only payment treatment. In addition, more farmers make more choices that minimize loss at the beginning where they had no experience of the choice tasks and hence had high uncertainty, and tend to make more choices that minimize a maximum opportunity loss (regret) with learning from choices in the earlier rounds. Having at least secondary education increase choices that minimize opportunity losses and maximize expected values.

A considerable gap remains in our understanding of the links between ecosystem services and poverty, and how pathways out of poverty may be achieved based on the sustainable utilization of ecosystem services. The second question of the thesis is pertinent to the link between the provisioning ecosystem services generated in agriculture and the nature of farmers' preferences for river ecosystem services (ES) improvements. This question is discussed in the second paper of the thesis, "Do Farmers in Developing Countries Value River Ecosystem Services improvements?" In this paper, we hypothesize that anticipated gains

from increasing yield or reduction of risk of crop losses resulted from improved ecological condition would reinforce (crowd in) farmers' preference for particular ES attributes. We specified four ES attributes; water supply reliability, flood protection, riparian vegetation and water quality, and conducted choice experiments on Ethiopian farmers. We employed a mixed logit model to analyze the data and estimate the parameters, and the coefficients on all ES attributes are statistically significant and have the expected signs. The farmers exhibit a significant willingness-to-pay (WTP) for all the specified ES attributes, and they are willing to pay more for ES attributes associated particularly with provisioning services from their farming. Counterevidence suggests that self-interested reasons (economic incentives) could undermine the positive attitude of people towards the environment, and reduce (crowd out) pro-environmental behaviors.

Previous studies and national policies focus on developing high yielding varieties and improving farm productivity, but farmers' adoption of high yielding varieties has been less than desirable. This thesis asks a question pertaining to the traits farmers give priority to when they make choices to adopt improved crop varieties in the age of climate change. The thesis discusses this question in the third paper, "Not my cup of Coffee: Trait preferences of farmers for coffee varieties." We use a choice experiment to elicit the coffee varietal preferences of farmers. The findings reveal that farmers have stronger preferences for yield stability traits such as disease resistance and weather tolerance than for a high yielding and early maturing traits.

Finally, the fourth question of this thesis is concerning the constraints to climate change adaptation and examined public environmental skepticism among the farmers and whether it matters in a payment for forest conservation. The topic that discusses this is, "How climate change skepticism affect preferences for forest conservation in developing countries". A contingent valuation survey is used to elicit the willingness to pay of farmers for forest conservation. The findings reveal that farmers have significant demand for forest conservation, and environmental skepticism variables explain the variations of WTP among the farmers.

In the remainder of this chapter, section 2 provides an overview on climate change adaptation and agriculture in Ethiopia. In this section, I revisit the literature on climate change adaptation in general and adaptation options and constraints for famers in developing countries in particular. Section 3 briefly describes and summarizes the methodologies employed to study farmers' technology choices under climate uncertainty, and preferences for river ecosystem services and forest conservation. Section 4 summarizes the four papers of the thesis and highlights the results. Section 5 provides overall concluding remarks, empirical implications and limitations of the thesis and some outlines for future research.

2. Climate Change: Adaptation, Impacts and Options

Evidence shows a steep increase in the atmospheric concentration of greenhouse gases, the major byproduct of burning fossil fuels for industrial activities and cutting forests (Keeling, *et al.*, 2005). In the broader sense, there are two main policy responses to this change: mitigation and adaptation. Since the climate change issue entered the international policy arena in the late 1980s and early 1990s (Burton, *et al.*, 2002), the initial "pollution" view of the climate change issue led to focus on climate change mitigation and sidelined adaptation. Mitigation measures seek to address the root cause by reducing greenhouse gas emissions, while adaptation seeks to reduce the risks posed by the consequences of climate change. Atmospheric scientists highlight concerns that climate change adaptation programs might interfere with the existing development programs, and thus bring unintended consequences to vulnerable groups (see Misra, 2017). Other studies (e.g., Burton, *et al.*, 2007; Pittock & Jones, 2000) argue that even if the emissions are relatively stabilized, climate change effects would last many years because of lag times in the climate system and the already large accumulation of past emissions.

There is growing evidence that the impacts of climate change have high adverse effects on agriculture, and the poor smallholder farmers in developing countries are the hardest hit (Bandara & Cai, 2014; Reyer, *et al.*, 2017; Wheeler & Von Braun, 2013). Not only is agriculture the most significant victim of climate change, it is also one of its main drivers.

More than eighty percent of the human-induced causes of adverse climate change are attributed to advanced industrial nations, but about eighty-five percent of the negative consequences of climate change are pitiably borne by the developing countries (Maikasuwa, 2013). The existing vulnerabilities of the poorest people who depend on semi-subsistence agriculture for their livelihood is exacerbated by the changing climate (IPCC, 2007; Slingo*, et al.*, 2005). All indications and consequences of climate change, such as droughts and floods, reduction of groundwater, more frequent and extreme weather events, increasing species extinction, and the spread of old and new diseases will directly affect agriculture, particularly in Sub-Saharan Africa (SSA) countries that have poor adaptive capacity.

Extensive literature is available on the effects of climate change on agriculture (Khanal*, et al.*, 2018; Mendelsohn*, et al.*, 1994; Schlenker*, et al.*, 2005). Most studies focus on industrial countries, and addressing adaptation needs in the context of small-scale, semi-subsistence agriculture in poor developing countries raises special challenges, because the adaptation measures could critically influence key national policies and goals related to poverty reduction, water, food, energy, and education and health. Therefore, adaptation options that contribute towards poverty reduction, improve human wellbeing and support for environmental sustainability are necessary to meet the need for effective adaptive capacity of farmers in developing countries. The imminent question therefore is what factors motivate the farmers' preferences for particular adaptation options, and how one can successfully harness the farmers to choose sustainable adaptation options in the face of climate change stressors.

Studies show supportive evidence for policy makers to consider farmers' existing knowledge and skills, and options in adapting to climate change (Khanal*, et al.*, 2018). Few studies examined the adaptation options and constraints for farmers in Ethiopia and other African countries (e.g., Bryan*, et al.*, 2009; Deressa*, et al.*, 2009). These studies report that farmers carry out different options such as crop variety adoptions, soil conservation, tree planting, changing planting time and irrigation uses in order to offset the adverse effects of climate change impact, while lack of information on climate change and financial constraints are the main barriers of adaptation. The process to institutionalize and integrate adaptation measures with national development programs therefore should consider the context of the

area and be in congruence with farmers' adaptation behavior and their preferences for adaptation measures.

2.1. Decisions under Risk and Uncertainty

Uncertainty and risk are essential features of agriculture. Innovative agricultural technologies increase the optimism of transition out of poverty, improve productivity and ensure food security. however, questions on the low technology adoption of farmers in developing countries remain unanswered (see Akay*, et al.*, 2012; Alene*, et al.*, 2000). Risk is an integral and important part of technology adaption, and the risk encountered from adoption of technologies such as new crop varieties, fertilizer, pesticide and other chemicals is not clearly quantifiable. Most studies assessed risk attitude and risk preferences of individuals under well-defined and measurable probabilities of the possible outcomes (e.g., Charness*, et al.*, 2013; Kahneman & Tversky, 1979). The rate of technology adoption and farm productivity of Ethiopian farmers are among the lowest in the world (Akay*, et al.*, 2012). There is very little systematic evidence on how farmers make technology adaption decisions in uncertain circumstances.

Economists conducted experiments and field surveys to explore the decision-making behavior of farmers in adopting new technologies. Large number of studies inspected the role of risk, uncertainty and learning in the adoption of new technologies (Aimin, 2010; Alpizar*, et al.*, 2011; Backus*, et al.*, 1997; Marra*, et al.*, 2003). Such studies presuppose well-defined and known probability, agents' understanding of probability and responsiveness to the probability changes and the study subjects are supposed to make their choices on the basis of reasonably stable, well-articulated and self-contained preferences. In contrast to this, experimental evidences by Butler and Loomes (2011) showed that choices are not always based on stable and well articulate preferences so much so that even most literate and numerate individuals cannot easily articulate and state their preferences under risk.

2.2. Agriculture and Irrigation Management

The Millennium Ecosystem Assessement - MA (2005) explored that supply of ES is decreasing, and meanwhile the demand is increasing: of the ES assessed by the MA (2005),

60% were declining, while the demands for over 80% of the services were increasing. The demand to increase the agro-ecosystem services or provisioning services in particular has been accompanied by a decline in regulating services and this affects human well-being and security, agricultural activities and ecological conditions. Most ecosystem studies in developing countries focus on the link between provisioning services and poverty alleviation (Suich, *et al.*, 2015), but they fail to show the direction of causality. The study by Suich, *et al.* (2015) pointed out that a considerable gap remains in understanding the direction of links between ESs and poverty alleviation, or how pathways out of poverty can be achieved based on the sustainable utilization of ES.

Agriculture sector is the biggest user of freshwater resource globally; it uses for irrigating crops and orchards, drinking water for domestic animals and for other farm activities (Meena & Jha, 2018). Climate change has reduced growth in crop yields by 1–2% per decade over the past century, and adverse impacts are projected to be growing in the future (Gourdji, *et al.*, 2013; IPCC, 2014). In addition, observations and projections about climate change have warned that one of the most significant adverse impacts of climate change is on the hydrological system, i.e., on river flows and regional water resources (Bates, *et al.*, 2008). Different communities and stakeholders adopt different strategies to use groundwater or rehabilitate rivers to mitigate the climate change impacts mainly for sustaining irrigation benefits.

Several choice experiment studies examine the benefits of river ecosystem services in developing countries (Andreopoulos, *et al.*, 2015; Birol & Das, 2010; Shi, *et al.*, 2016; Zander, *et al.*, 2010; Zander & Straton, 2010). However, these studies have not attempted to assess if the expected gains from farming, i.e. provisioning services generated in agriculture, could reinforce the preferences for river ES, and strengthen the potential for sustainable use of river water and other ecosystem services. Paper II examines the nature of farmers' preferences of river ecosystem services, and sheds light on the potential of agriculture sector to reinforce the demand for sustainable use of ES surrounding rivers.

2.3. Improved Crop Variety adoption

Farm productivity in Ethiopia is among the lowest in the world (Akay*, et al.*, 2012). Studies in developing countries examined the impact of adoption of improved crop varieties and socioeconomic factors affecting their adoption decisions (Alene*, et al.*, 2000; Kassie*, et al.*, 2017; Khonje*, et al.*, 2015; Shiferaw*, et al.*, 2014; Shiferaw*, et al.*, 2008; Verkaart*, et al.*, 2017). Policy makers and most previous studies emphasize on evaluating the importance of increasing crop yields. Evidences also reveal that the adoption of improved varieties is less than desirable (e.g., Dalton, 2004; Shiferaw*, et al.*, 2014; Zeng*, et al.*, 2014). Few studies conduct choice experiments to study the trait preferences of farmers for maize and "Teff" (Asrat*, et al.*, 2010; Kassie*, et al.*, 2017). Their findings showed that farmers have strong preferences for drought tolerant traits. However, very little is known about the traits preferences of Ethiopian farmers for coffee varieties in the age of climate change.

Ethiopia is home of origin of Arabica coffee and the largest harbor of wide-range of coffee genetic biodiversity in the world. There are four different modes of coffee production system: forest coffee, semi-forest coffee, garden coffee and plantation coffee. These production systems differ in terms of yield, forest disturbance and dimension of coffee varieties. The yield in forest coffee and semi-forest coffee are less than the national average productivity, but are rich in terms of coffee genetic biodiversity they harbor. Meeting the growing demand for increasing production while safeguarding the genetic biodiversity of coffee is the challenge for policy makers. The beginning of biotechnology and conservation of genetic resources provides the optimism to improve phenotypes of high economic importance and bring socially desirable outcomes. Knowledge on the trait preferences of farmers can enable to develop new varieties being demanded by the farmers and adapt to climate change. Exploring the preference heterogeneities among the farmers and their sources, if any, enable targeted communication programs, differentiated product offerings, market segments and market niches (Allenby & Rossi, 1999). This can increase the dissemination and adoption of improved varieties. In comparison to other annual crops, coffee as a perennial plant is arguably more robust to weather shocks but the practice of coffee farming is more challenging because of the less flexibility for inter-annual agronomic adjustments, long lasting effects of once made decisions and great ecological importance. Understanding the

trait preferences of farmers can also help to complement the *in-situ*, on-farm, conservation by targeting at the traits the farmers prefer less to maintain on their farms.

2.4. Forest conservation

Forests play important role in human wellbeing. There is an increasing recognition for the value of forests: forests are nature's atmospheric carbon sink and provide wildlife with a suitable habitat for living along with filtering ground water and preventing runoff. Wide literature is available on the value of goods and services from forests such as biodiversity conservation (Christie*, et al.*, 2006; Czajkowski*, et al.*, 2009; Giergiczny*, et al.*, 2015; Gowdy, 1997; Lindhjem*, et al.*, 2015), carbon sequestration (I. J. Bateman & Lovett, 2000; Boyland, 2006; Guitart & Rodriguez, 2010; Sedjo & Sohngen, 2012), recreation (Bartczak*, et al.*, 2008; Stenger*, et al.*, 2009) etc. The biodiversity in turn plays crucial role in maintaining ecosystem resilience to exogenous shocks from climate change (Oliver*, et al.*, 2015), and ecosystem functioning (Hooper*, et al.*, 2005).

Many contingent valuation studies often ask respondents whether they would vote for an environmental change at some costs and examine the socioeconomic factors that determine respondents' decisions to vote for or against the new environmental scenario. Evidences showed, however, patterns of environmental attitudes and other human behaviors such as public environmental skepticism might predict environmental decisions and outcomes. Climate change skepticism attitudes reflect the disposition of subjects' thought, belief and view on the cause and consequences of climate change and hence solutions for related problems.

Environmental skepticism, ranging from outright denial to general uncertainty, appears a pervasive social phenomena (Hobson & Niemeyer, 2013). Evidences indicate that public environmental skepticism are increasing (Whitmarsh, 2011), and the growing anti-environmental campaigns purport environmental problems are exaggerated (Dunlap, 2013). Outright rejection of environmental threats and climate change happening among the public might be relatively unchanging, but the proportion of people who claims the issues are exaggerated is increasing over time (Whitmarsh, 2011). This milder form of skepticism with

its broader popular base can be an even greater barrier to implement sustainable adaptation measures.

3. Methods

This thesis attempts to understand and map farmers' preferences for climate change adaptation measures in a developing country context. Integrating sustainable environmental policies that improve adaptive capacity in agriculture into national development policies requires understanding how farmers make economic decisions under uncertain circumstances, identifying sustainable adaptation options and evaluating the nature of farmers' preferences for the adaptation options and inspecting factors motivating and restraining their choices is important. Economic and psychological factors might influence the preferences for adaptation options. In mapping the preferences of farmers, all the papers in this thesis employ discrete choice models, which are bases mainly in random utility theory. Random utility theory postulates that individuals choose what they want or prefer; and where they do not, it can be explained by random factors.

3.1. Random Utility Model (RUM)

The concept of utility was originally developed by Thurstone (1927) as a psychological stimuli and it was first used to test whether respondents can differentiate between levels of stimulus. Then, Marschak (1960) interpreted the idea of stimuli as utility and provide a foundation for random utility theory. Then, it received a wider application in economics and marketing of goods, and was used to explain choice inconsistencies often reflected by subjects. In a random utility model (RUM), the evaluation of a stimulus by a subject is modeled by a random variable from which a sample is taken at each presentation of stimulus (Koppen, 2001).

Random utility maximization theory (McFadden, 1974), is currently the most common approach in stated preference methods. It assumes that each individual has a utility function associated with each of the alternatives considered. Discrete choices in stated preference methods and experimental designs construct settings where the subject is requested to choose on the basis of his/her preferences. The individual utility function includes a

systematic part based on the observed explanatory variables, and a random part that includes the effects unaccounted by the observable factors.

The utility functions describing standard discrete choice is given by:

$$U_{jn} = X_{jn}\beta + \varepsilon_{jn} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (1.1)$$

$$y_{jn} = \begin{cases} 1 \; if \; U_{jn} \geq U_{kn} \\ 0 \; otherwise \end{cases} \forall k \in S_n, k \neq j$$

Where U_{jn} corresponds to the utility of individual n for alternative j; X_{jn} is a vector of attributes of alternative j and socioeconomic characteristics of individual n; β is a vector of unknown parameters; ε is the error term capturing different sources of uncertainty such as measurement errors and unobserved individual characteristics; y_{jn} indicates whether alternative j is chosen by individual n or not, and S_n corresponds to the set of available alternatives. The probability of choices can be affected by self-interest motives, risk preferences, socioeconomic characteristics or environmental attitudes.

In Paper I, we employed farmed field experiment (FFE) to explore the decision criteria that farmers use to make choices under hard uncertainty, test the consistency of choices and whether choice behaviors vary among farmers. The experiment uses real incentives where the reward of the subject depends on her/his own action. The incentive attached with the choices would induce individuals to consider their actions and maximize their self-interest. The rest of the papers try to look at evidence about the nature of preferences for particular adaptation options. Paper II examines farmers' preference for river ecosystem services improvements; Paper III assesses the trait preferences of farmers for coffee variety; and Paper IV discusses public environmental skepticism and its effect on willingness to pay for forest conservation. The problems in three papers, therefore, by necessity employ stated preference methods: contingent valuation (CV) and choice experiment (CE).

The extent to which the results of the stated preference and field experiments are relevant to a particular question or problem depends on the degree to which the instrument or the setting captures the important features of the problem. This conundrum is the same to any model: the experiment cannot usefully inform policies when one simplifies (assumes away)

too much, and the experiment becomes an overly complex model that does not identify the key policy variables or response when one simplifies too little. Therefore, the solution is to get the "right" amount of context, whether that is the right amount of realistic detail and financial incentives in an experiment, the right amount of information to provide respondents with in a stated preference study, or the right number and definition of explanatory variables in an econometric analysis.

3.2. Stated Preference Methods

Stated preference (SP) methods are used to estimate the economic values of environmental goods and services using survey question. SP has multiple variants. The most common approaches are CV and CE methods. In dichotomous choice CV approach, respondents are asked whether they would vote for a proposed change at specified cost whereas in CE, respondents are asked to state their preference among two or multi-attribute alternatives. Many economists have strong bias in favor of estimates from revealed preference as opposed to SP data. However, SP methods are sometimes the only tools available especially in cases where researchers and policy makers are interested in estimating the value of non-market goods or those with passive use values. The validity of SP methods, especially, the hypothetical bias has been widely debated for several decades. However, there is a consensus that most of the arguments against stated preference methods can be avoided by careful design and implementation.

3.2.1. Contingent Valuation

In contingent valuation, studies ask respondents to report their willingness to pay (WTP) to obtain good, or willingness to accept (WTA) to give up a good, or ask whether they would vote for or against a proposed environmental change at some costs, rather than inferring from observed behaviors in regular market places. Several studies employed CV methods to estimate the total economic value of a change in public goods such as forest biodiversity, water quality, air quality and other use and non-use values at some cost. CV method has flaws to measure nonuse values (Diamond & Hausman, 1994). Evidence reports that the possibility of WTP-WTA gaps for different reasons; subjects' misconception (Fehr*, et al.*, 2015) and endowment effect (Plott & Zeiler, 2005). Similarly, Kahneman and Knetsch (1992) expressed

the tendency to of WTP responses to be highly similar across different surveys even if the theory suggests otherwise –embedding effect.

Dichotomous Choice (DC) CV studies steadily produced significantly higher estimates in comparison to open ended CV formats (Frykblom & Shogren, 2000). Studies reported that respondents' incentive compatibility not to reveal their true WTP (Wertenbroch & Skiera, 2002), the degree of information provided (Hanley*, et al.*, 1995), framing (Green*, et al.*, 1998), reference point and anchoring (Bergman*, et al.*, 2010) and yea saying (Bateman*, et al.*, 2006) are factors that raise concerns on WTP estimates from CV instruments. 'Yea-saying' occurs when respondents tend to say 'yes' for the program; i) without seriously considering the costs (Nguyen*, et al.*, 2013), ii) in the desire to fulfil some accepted sense of social responsibility, and iii) an attempt to please the survey interviewers.

Studies often regress on socioeconomic factors to examine factors that predict respondents' decisions to vote for or against the new environmental scenario. Evidences showed that patterns of attitudes and other unobservable human behavior such as public environmental skepticism might predict respondent's decisions and environmental outcomes. Climate change skepticism attitudes might reflect the disposition of thoughts, beliefs and views on the causes and consequences of climate change and hence solutions for related problems.

3.2.2. Discrete Choice Experiment

Discrete choice experiment is a strand of stated preference methods used to estimate the value of goods, services, policy and programs that can be expressed based on characteristics or attributes and levels that these attributes can take. The theoretical foundation of this method combines the characteristics theory of value (Lancaster, 1966), and random utility theory (Manski, 1977; Thurstone, 1927). CEs were used in marketing and transport economics studies (Louviere & Hensher, 1982; Louviere & Woodworth, 1983), but are increasingly being applied to other fields such as environment, agriculture and health. CEs differ from typical conjoint methods in that individuals are asked to choose from alternative bundles of attributes instead of ranking or rating them. In CEs, respondents are asked to choose between different bundles of (environmental or agricultural) goods, which are described in terms of their attributes, or characteristics, and the levels that these take.

The CE method is a generalization of contingent valuation technique: rather than asking people to choose between a base case and a specific alternative, CEs ask people to choose between cases that are described by attributes (Adamowicz*, et al.*, 1998). If appropriately designed, CEs offer several advantages: they are consistent with random utility theory and useful as a method of eliciting passive use values. Several CE studies on a variety of environmental and agricultural issues are conducted in developing countries (e.g., Gibson*, et al.*, 2016; Keeling*, et al.*, 2005; Roessler*, et al.*, 2008) to inform environmental and agricultural policies.

3.3. Framed Field Experiment

Experimental economics has been also growing over the past 50 years. Field experiments take the data generation process beyond the walls of the laboratory and in moving closer toward how naturally occurring data are generated. Harrison and List (2004) denoted a framed field experiment (FFE) with field context in the commodity, task, stakes, or information set that the subjects can use. Participants in a lab-experiment are standard subjects such as campus students whereas participants in FFE are nonstandard subjects or subjects recruited from a population who make actual decision in a field. Field experiments, if well designed, tackle counterfactual problem and provide naturally occurring setting to control the variable of interest, but cannot necessarily control the changing context of the environment.

When there are important factors that might influence behavior, one might get closer toward the environment of ultimate interest using FFEs, and learn whether and to what extent such factors influence behavior one after another. The growth of experimental economics studies is encouraging, but concerns on external validity, replicability, substantiality and the applicability of the method to mainstream economics remain (List & Metcalfe, 2014). The subjects in this experiment are farmers from developing country who make actual economic decisions in related tasks. This could bring their real world experience, improving the representativeness of the experimental context to the real world decision problem and this adds validity to the conclusion drawn (Harrison & List, 2004).

3.4. Study area: Ethiopia

Ethiopia is the second most populous country in Africa next to Nigeria, and one of the fastest growing economies in the world. Agriculture is the main livelihood for the majority of households in the country, and the largest contributor to the economy. Agriculture provides employment for 81% of the population, and accounts for 40% of the gross domestic product (Di Falco*, et al.*, 2012). Ethiopia is also the largest producer of Arabica Coffee in the world, and harbors a wide coffee genetic diversity.

The country is experiencing the effects of climate change; as it has seen frequent and large changes in river flow and fewer normal years, and more years of both drought and flooding (Siam & Eltahir, 2017). The rainfall variability along with the increasing population growth puts pressure on the available water resources, and becomes a challenge for agriculture and environmental conservation. The direct effects of climate change, such as an increase in average temperature or a change in rainfall patterns also provides the necessity and opportunity to switch to a new and sustainable development model.

The government of Ethiopia has therefore initiated the Climate-Resilient Green Economy (CRGE) initiative to protect the country from the adverse effects of climate change, and to build a green economy that will help realize its ambition of reaching middle-income status before 2025. Improving agricultural productivity to ensure food security and farmers' income, while reducing emissions and protecting and re-establishing forest for their economic and ecosystem services including carbon stocks, are among the pillars to meeting the ambitious CRGE plan. This thesis contributes to understanding the nature of farmers' preferences for ecosystem services and climate adaptation measures, as well as the factors affecting their preferences.

4. Summary of the papers

This section summarizes each paper in the thesis. It includes brief explanations of the methods used in the study and summary of the main results. Paper I concerns on the decision-making behavior of farmers under hard uncertainty, while Paper II to Paper IV use

stated preference methods to examine evidences about the preference of farmers for climate change adaptation measures.

4.1 Paper I: Exploring Farmers' Technology Preferences under Hard Uncertainty: Experimenting on Reference Point and Learning

Using a data from framed field experiment with real incentives on farmers in northern Ethiopian, this paper addresses three questions. First, do farmers use minimax criterion (to minimize loss), minimax regret (to minimize the maximum regret or opportunity loss), or maximum expected value criterion (to maximize expected value) to choose technology under hard uncertainty? Second, do farmers consistently use the same criterion, or deviate with the pay modalities or experience of the choice tasks? Third, what observable socioeconomic factors predict farmers' choices of criterion? To test the consistency of choices, we design two different payment modes and split participants randomly into two groups. Farmers in one group receive their payment in cash only, while farmers in the second group can receive their payment in either cash or in-kind (shovel) depending on their own choosing, if they pass a threshold limit, Ethiopia birr 90 (the price of shovel at the wholesale market in the regional capital city). All farmers prefer to receive their payments in the form of in-kind payment (shovel), and this indicates that the in-kind payment has higher value than cash payment equivalent to the price wholesale market. However, only the participants under the in-kind/cash optional payment who pass the threshold limit receive the in-kind payment.

The results show that no single decision criterion is dominant in the two payment modes and in all rounds of choices. Farmers' choices under hard uncertainty are not consistent: more farmers make choices consistent with minimax criterion under the in-kind payment with references than under the cash only payment. The reference point (threshold limit) to receive the in-kind payment might increase loss aversion and make farmers choose more choices that minimize loss.

Farmers in the two groups also make more choices that minimize loss at the beginning, but choices consistent with minimax criterion continue dominating the choices of farmer under the in-kind option. With getting experience from choices in the earlier rounds (learning),

farmers tend to make more choices that minimize the maximum opportunity loss (regret) in the later rounds. Repeated experiences of losses in the earlier rounds increases the likelihood of making choices consistent with minimax criterion. Farmers with at least secondary education are more likely to make choices that minimize opportunity loss or choices that maximize expected values. The findings give insights how to increase agricultural technology adoption in semi-arid and rain-fed areas where farmers face rainfall risks and shocks.

4.2. Do Farmers in Developing Countries Value River Ecosystem Services improvements? A Choice Experiment of Ethiopian Farmers´ Adoption of Sustainable Management Strategies.

This paper conducted choice experiments on smallholder farmers from north Ethiopia to map the nature of their preferences for river ecosystem services improvements in the face of climate change. This paper specifies four river ecosystem services (ES) attributes: water supply reliability, flood protection walls, riparian vegetation and water quality on nearby rivers. These river ecosystems have association with the provisioning services generated in agriculture and hence some farmers could derive direct uses such as more production from better irrigation use, nectar for their bees and avoiding risk of yield losses while others derive only indirect uses and option values. In this paper, we assume the definition of Millennium Ecosystem Assessement - MA (2005) for agricultural production as provisioning services and assess its effect on farmers' preferences for these ES improvements around rivers.

This paper addresses three questions. i) How much money are farmers willing to pay for improvements of river ES attributes? ii) Do preferences for the ES attributes exhibit variations among the farmers? iii) Does implicit self-interest motives in terms of the provisioning services generated in agriculture explain the preference heterogeneities among the farmers? We estimate the willingness to pay of farmers, and find that they have significant positive demand for the improvements of the four ecosystem attributes. In comparison, farmers reveal stronger preferences for the improvements of flood protection and water quality services than for the increment of river water supply and regeneration of riparian vegetation.

We employ a mixed logit model to test for preference heterogeneity among the smallholder farm households, and examine the sources of heterogeneity. We find evidence for the presence of preference heterogeneity; which is explained by differences in socioeconomic factors such as age, farm size, access to irrigable land, and the distance of the plot to a river. Households led by older people are willing to pay less for the improvements of ES around rivers, perhaps because they have fewer remaining life years than younger household heads and thus give lower priority to long-term oriented environmental programs. Households also exhibit strong preferences for the four river ecosystem service attributes, and strongest for attributes related to the provisioning service in terms of their farming. Thus, households with irrigable farmland and larger farm size are willing to pay more for increasing water supply from the rivers; households with larger farm size and farm plots nearby the rivers are willing to pay more for flood protection measures, and households engaged on beekeeping are willing to pay more for regeneration of riparian vegetation. This knowledge can be utilized to design incentive schemes and management strategies for farmers to become the main stewards as well as beneficiaries of ecosystem services.

4.3. Paper III: Not my cup of coffee: Trait preferences of farmers for Coffee Variety - Lessons for Crop Breeding in the Age of Climate Change

This paper investigates the trait preferences of farmers for coffee varieties, and assesses the traits farmers give priority to when they decide to cultivate or sustain particular coffee varieties on their farmed fields. In this paper, we conducted choice experiments on North Ethiopian farmers to estimate their willingness to pay for the improvements of coffee traits, explore the nature of trait preferences for coffee variety and sources of preferences heterogeneity among the farmers. Previous studies and policy makers give emphasis to the improvements of high yielding technologies, but farmers' adoption of high yielding varieties is low and less than socially desirable. This paper included five coffee attributes including improvements in yield per hectare, weather tolerance, disease resistance, maturity duration and seedling costs, and used experimental design to create the choice sets and alternative coffee varieties offered to the farmers for experimenting on their trait preferences.

In computing the estimated coefficients, we set the coefficient for non-monetary attributes such as yield, weather tolerance, disease resistance and maturity duration to be random

parameters with a normal distribution and make the coefficient on seedling cost fixed so that it is possible to estimate the monetary value of changes in the attributes. The results show that the coefficients on all attributes are significant, indicating that the attributes are relevant to farmers' choice of coffee variety.

Farmers demonstrate stronger preferences for stable yield traits such as disease resistant and weather tolerant varieties than for high yielding and early maturing varieties, but preferences for the traits also exhibit heterogeneity among the farmers. The results show that farmers with access to irrigable land exhibit weaker preference for weather resistant coffee traits. Farmers with more years of experience of coffee farming exhibit stronger preferences for high yielding traits and early maturing traits than those that had no experience in coffee farming. In contrast, farmers with more years of education exhibit weaker preferences for early maturing traits and for diseases resistance traits. Understanding farmers' preferences for crop varieties in the age of climate change provides useful information for the design of national policies and crop breeding programs to develop improved varieties by integrating the traits farmers' prefer most , which can increase the uptake of these new varieties by the farmers

4.4. Paper IV: How Climate Change Skepticisms affect Preferences for Forest Conservation in Developing Countries?

Using data from a contingent valuation survey conducted on farmers in northern Ethiopia, paper IV explores the effect of environmental skepticism on farmers' preferences for forest conservation in terms of limiting their willingness to pay for improvements of forest conservation. A total of 358 randomly selected smallholder farmers are surveyed in this study. We measure household's degree of environmental skepticism by asking them to what extent they agree with some accounts on the causes, consequences and proposed solution of climate change, using a 1-10 Likert scale (where "1" is 'do not agree at all' and "10" is 'completely agree'). The objective is to test statistically if there is enough evidence for a decline in pro-environmental behavior with a mounting public environmental skepticism, and the evidence show that farmers' high environmental skepticism reduces their willingness to pay.

The exploration of public environmental skepticism as a predictor of willingness to pay for improved forest conservation is a novel aspect of this paper. The farmers reveal significant demand for forest conservation, and are willing to pay a substantial amount of money for improved biodiversity conservation. However, the high skepticism towards experts' view of the climate causes and media's discussion of the seriousness of climate change is weakening the pro-environmental behavior. For example, respondents stating high certainty for "God is the cause of climate change" and "Medias are exaggerating the seriousness of climate change" exhibit lower WTP for forest conservation in this experiment. Other socioeconomic factors such as age and pro-social attitudes are also found to have significant effects on the pro-environmental behaviors.

5. Contribution, Limitations and Outlines of Future Research

This section reports the contributions of this thesis, briefly explains methodological limitations and outlines possible future research.

5.1. Contribution

This thesis sheds light on adaptation behavior of smallholder farmers and maps their preferences for adaptation measures. This thesis uses stated preference and field experiments to examine their choice behavior under uncertain circumstances, the nature of preferences for climate adaptation measures and their attributes, and identifies the constraints to sustainable adaptation options. The thesis contributes empirical evidences to the literature on smallholder farmers' preferences for adaptation measures in a developing country context.

The main methodological contribution of the thesis is the use of field experiments to test the effect of reference setting (payment mode) on decision-making behavior under hard uncertainty. Not only are the results from the experiment relevant for policymaking, but also researchers may benefit from employing this method in combination with other options, and by modifying it in accordance with the questions they aim to address.

5.2. Limitations and Future Research

This thesis is based on stated preference and field experiment data. In collecting the data we followed standardized and thoroughly developed research protocol, and took utmost care to control for factors we suspected could confound participants* responses. Yet, biases might still be present. For example low level of understanding of farmers due to high level of illiteracy, experimental fatigue, and the hypothetical nature of the choice experiment and contingent valuation questions could affect farmers' responses. The fact that many of the participants are close acquaintances of the local administrative leaders who were supporting us in organizing and coordinating the survey of respondents could also affect their responses. Despite our utmost efforts to assure them that this study has nothing to do with the government programs in the study area, and that their anonymity would be guaranteed, they sometimes kept mentioning the government while answering the questions.

This thesis started with addressing the question of farmers' decision-making behavior under hard uncertainty, where complex interactions of different observable and unobservable factors can affect decision-making behavior. In Paper I, we designed a framed field experiment to test which of three decision criteria: i.e., minimax, minimax regret or expected value maximization, farmers use to make choices under hard uncertainty. This study (over)simplifies the complexity; and reduces the payment setting into two: cash only payment and in-kind/cash option, and tests only three decision criteria. In these face-to-face interviews, the presence of the interviewers can affect farmers' decision-making; e.g. by responding in ways they think satisfice the interviewer and/or are most socially acceptable. Randomized control trials and natural experiments could provide the opportunity to address the observer effect and reduce bias. Future studies could also include tests of more decision criteria, and use different stake values and/or reference points in the incentivized experiment to better understand farmer´s choices under hard uncertainty.

In Papers II and III, we employ choice experiments. Despite our best efforts, the inherent limitations of stated preference methods, for example hypothetical bias, analysts' subjective decisions in specifying utility functions and experimental design might still influence the findings. Therefore, more stated preference studies are needed to verify these results, and to

test the transferability of these results to smallholder farmers in developing countries in general.

Finally, Paper IV examined public environmental skepticism and its effect on farmers' payment for forest conservation, using a 1-10 Likert scale to determine the degree of farmers' environmental skepticism (in terms of their level of agreement of selected statements), while double bound dichotomous choice (DBDC) contingent valuation (CV) is used to elicit their WTP for conservation. To address the issue of hypothetical bias often raised to CV studies, future studies could use incentive alignment techniques (e.g., Ding*, et al.*, 2005) to reveal the "true" WTP of respondents.

5.3. Overall Conclusion

The thesis presents evidence that choices of farmers under hard uncertainty depend on reference points relative to which they evaluate their outcomes as gains or losses. Farmer make choices that minimize loss and reveal high loss aversion when there is a reference point in terms of a threshold limit to receive in-kind payment. Results also exhibit significant and positive demands of farmers for river ES attributes, and the presence of preference heterogeneities among farmers. Farmers are willing to pay the most for ES attributes associated with the improvements of provisioning services on their private farming. Farmers also exhibit stronger preferences for yield stability traits, weather tolerant and disease resistant traits than for high yield and early maturing traits. These results can be useful for environmental decision-making, wider cost-benefit analyses, and welfare aggregation. In other contexts, public environmental skepticism and lack of sufficient awareness of deforestation are found to restrain payments for forest protection. This finding is useful when designing measures to improve the awareness of deforestation, global warming and climate change impacts in order to improve commitments for environmental protection.

We draw the following conclusions and policy implications based on the stated preference and field experiment evidence from this thesis.

1. **Decisions under uncertainty are reference dependent.** People make decisions based on the potential value of gains and losses, when the probabilities of outcomes are unknown. Setting an explicit reference level, in terms of a threshold limit to receive

payments in in-kind (instead of cash only), increases farmers' loss aversion and the probability of choosing the safest and the most conservative decision criterion available.

2. **Learning improves decisions under uncertainty.** Farmers with at least secondary education are more likely to make choices that minimize the maximum opportunity losses or optimal choices under uncertainty. In addition, learning from completing choice tasks in earlier rounds increases the probability of making choices that minimize the maximum regret.
3. **Self-interest motivates selective pro-nature preferences.** Farmers generally reveal significant and positive demand for the improvements of ecosystem services from nearby rivers-. However, these positive preferences seem closely connected to farmers´ self-interest in terms of those services which have a direct effect on their crop yields. Thus, farmers with access to irrigable land have the strongest preferences for water supply reliability, farmers who have farm plots further away from rivers reveal weaker preferences for flood protection services, and farmers engaged in beekeeping reveal stronger preferences for riparian vegetation.
4. **Farmers have stronger preferences for stable yield traits.** Farmers are willing to give up an increase in yield to receive stable yield year after year in the face of environmental stressors like weather variability and coffee diseases, both of which can increase with climate change.
5. **Public environmental skepticism reduces support for forest conservation.** Environmental skepticism have a significant, negative effect on farmers' preferences for forest conservation.

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Exploring Farmers' Technology Preferences under Hard Uncertainty: Experimenting on Decision Criteria[1]

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Abstract

Farmers' pay-off from adapting new technologies, in forms of new crop varieties, fertilizer and pesticide use in response to droughts and other extreme weather events, is uncertain. In a field experiment with real payments to nearly 400 North Ethiopian farmers, we examine the decision criteria they use when making technology adaption decisions under hard uncertainty. One group of farmers receive payments from technology adaption in cash only, while the other group can choose between in-kind or cash payments if they pass a threshold in their payoff from the experiment. We assess whether farmers mainly use minimax, minimax regret or maximum expected value criteria to make choices under uncertainty, and test whether the decision criteria they use are consistent across the two payment modes and in consecutive choice tasks. The results show that farmers' choices under hard uncertainty are not arbitrary nor random, and they strongly depend on reference points. Choices consistent with the minimax criterion are dominant under the in-kind payment mode, but no decision criterion clearly dominates under the cash only payment. We also find that learning in terms of farmers' increased experience from going through the choice tasks, which might increase their understanding of the game, increases choices consistent with the minimax regret and maximum expected value criteria. Most farmers make choices consistent with the minimax criterion, the safest and most conservative criteria available under high uncertainty. We also examine the socioeconomic determinants of technology adaption under hard uncertainty. The results give insights to tailor design of policies to promote technology adoption and boost farm productivity in semi-arid and rain-fed agricultural areas where farmers face rainfall risks and shocks.

Key words: Field Experiment; Uncertainty; Decision Criteria; Technology Preference; Reference; Learning
JEL: C93; D81; D84; O12; O14; Q16

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1. Introduction

Progress on innovative agricultural technologies such as improved fertilizer and high-yielding varieties, has increased the optimism of transition out of poverty in poor developing countries; however, questions on the low technology adoption of farmers remain unanswered (see Akay*, et al.*, 2012; Alene*, et al.*, 2000). In Ethiopia, rain-fed agriculture is the main means of livelihood, and it is sensitive to weather and climate variabilities. The rate of technology adoption and farm productivity are among the lowest in the world (Akay*, et al.*, 2012). The uncertainty encountered from weather variabilities, adoption of new technologies such as new crop varieties, fertilizer, pesticide and other chemicals is not clearly quantifiable. In spite of that, most studies focus on assessing risk preferences under well-defined and measurable probabilities of the possible outcomes (e.g., Charness*, et al.*, 2013; Kahneman & Tversky, 1979). There is little evidence, however, on how farmers make decisions on technology adaption under hard uncertainty[2].

This study aims to understand the nature and pattern of farmers' decision-making behavior under hard uncertainty, and investigates the decision criteria farmers use to make technology adoptions and factors influencing the choice criteria under uncertainty using incentivized experiment. In this paper, we design three prospects that correspond to three different decision criteria: i) Minimax (MMM), ii) Minimax regret (MMR) and iii) Maximum expected value (MEV) criteria. Each of the three prospects representing the three decision criteria has two possible outcomes: maximum and minimum outcome. The MMM criterion is the most conservative criterion, and selects the prospect that has the maximum minimum outcome (minimum loss). The MMR criterion selects the prospect that has minimum opportunity loss (regret) and the MEV criterion selects the prospect with the highest expected value (EV) under equal probability $(1/n)$ of n events occurring. Then, we test whether farmers' choices of decision criteria are consistent under different payment settings and in the subsequent rounds of choices.

[2] Hard uncertainty" is a situation when the set of probabilities of events occurring is not known (see Blackwell*, et al.*, 2007).

To investigate the decision-making behavior of farmers under different settings, we split the subjects randomly into two groups, and treat them with different payment modes. One group receives payments in cash only; while the other group can choose to get paid in-kind or in cash, if they pass the threshold. Every subject that passed the threshold preferred to receive his or her payments in-kind, which indicates that subjects have a higher perceived value of the in-kind payment. The participants can receive the in-kind payment (a shovel) only if they pass the price of the commodity at the wholesale market in the regional state's capital city (90 Ethiopian Birr), which is lower than the price at local market. The remainder amount is paid in cash if the participants score more than the threshold at the end of the experiment. In prospect theory (Kahneman & Tversky, 1979), people evaluate outcomes relative to reference points, and classify them as gains or losses. Franken*, et al.* (2006) argued that whether individuals perceive the final consequence of their choices as a loss or as a gain depends on their point of reference. A similar study by Blackwell*, et al.* (2007) of campus students showed that the students have no dominant decision criteria when making choices, but the majority of them make choices consistent with the MMR criterion. High stake increased the number of choices consistent with MMM, being the safest criterion. According to Holt and Laury (2005), the increased tendency to choose the safe option as the stakes get higher is an indication of increasing relative risk aversion. Blackwell*, et al.* (2007) added that contexts might affect decisions under uncertainty. Therefore, climate change adaptation and technology adaption studies that aim to minimize loss or maximize benefits under uncertain circumstances can benefit from considering references points in examining how farmers in the field make decisions.

The main concern in decision-making experiments is whether subjects understand and pay sufficient attention to the decision tasks and their choices, and not just quickly and randomly respond to the questions to 'get it over and done with'. The use of real payments (incentives) directly linked to farmers' choices of prospects can avoid this, as it gives incentives to carefully consider their choices (Battalio*, et al.*, 1990; Holt & Laury, 2002). Subjects also receive feedbacks of outcomes of their choices in each round before they make another choice in the next round. This enables us to examine whether farmers were learning from their previous experiences, or simply adapting and reacting to the feedbacks. There are two

different pieces of evidence on learning. Some scholars (e.g., Thaler*, et al.*, 1997) argue that decision makers can learn from experience, while others (e.g., Einhorn & Hogarth, 1978; Tellis & Gaeth, 1990) argue that experience may not lead to any substantive learning.

The results show that choices under uncertainty are not consistent but strongly depend on the reference point (payment mode): most farmers make choices that minimize loss under the in-kind payment. With learning and experiences, farmers shift from making choices that minimize loss to choices that minimize regret or choices that maximize expected value. The results also show that secondary education or above increases the probability of making choices that minimize the maximum regret and maximize expected value, while repeated experience of losses (minimum outcomes) in the previous rounds reduces it. Understanding farmers' decision-making behavior under uncertainty and factors influencing their choices helps to tailor mechanisms to increase farmers' adaption of improved farm technologies to boost farm productivity.

2. Decision Making and Uncertainty

Farmers make decisions that involve risks in their daily activities. The uncertainty that farmers encounter from weather and climate variability or adopting new technologies such as crop varieties, fertilizer and pesticide and other chemicals uses is not clearly quantifiable. Therefore, optimal theories under well-defined risk cannot explain choice behaviors under uncertainty like a game against nature which farming is. Ellsberg (1961) demonstrated that individuals prefer well-defined risk to ambiguous risk – uncertainty. Despite of the fact that uncertainty is an integral factor in most of daily circumstances, several studies focus on assessing risk preferences and decision making behavior of subjects under well-defined and measurable probabilities of the possible outcomes (e.g., Charness*, et al.*, 2013; Kahneman & Tversky, 1979).

There is no widely accepted normative or positive theory of decision making behavior under hard uncertainty (Blackwell*, et al.*, 2007). Knight (1921) makes the distinction between risk and uncertainty. He defines risk as a situation where the decision maker knows the alternative outcomes and probabilities, whereas uncertainty is a situation where the

decision maker does not know the probability of alternative outcomes, but may or may not know the outcomes that can occur. Most studies on decision-making under risk focused on situations described with known probabilities for all possible outcomes, and the principle of expected utility (EU) theory is regarded as rational choice – normative theory. The EU does not apply to a game against nature, because nature does not offer any way of assigning a probability to each possible outcome. Rather, decision criteria such as Minimax criterion (Wald, 1950), Minimax regret criterion (Savage, 1951), expected value maximizing (Laplace's) criterion, and maximum weighted average (Hurwicz, 1953) are used to explain decision making behavior when no information is available on the probability of occurrence of events.

Wald (1950), in minimizing maximum loss, formulated the problem of statistical decision making as a type of playing a game against nature, and proposed minimax (MMM) rule that supports the alternative whose lowest possible outcome is the maximum possible. This decision criterion calculates outcomes for each alternative under consideration by any probability distributions, and chooses an alternative with a maximum minimal outcome. Alternatively, Savage (1951) suggested the minimax regret (MMR) criterion, where regret is defined as the difference between the maximum possible outcome, which can be gained under any strategy given a certain state of the world and the actual amount gained under the strategy adopted. The MEV (LaPlace) criterion essentially assumes that the unknown probability of each event (n) occurring is equal ($1/n$), and that the player should choose the strategy that maximizes the "expected" payoff. None of these decision criteria commands general acceptance, and each can be applied to show peculiar consequences under some conditions (Savage, 1951).

For collective decision studies under uncertainty, such as the management of endangered species or avoiding irreversible depletion of resources, Bishop (1978) prescribes the necessity of applying the MMM criterion as a guide to safe minimum standard approach (SMS) unless the cost of doing so is unacceptably large. The SMS approach is a collective choice process that prescribes protecting some minimum level (safe standard) of renewable resources. However, the MMM criterion is criticized for ignoring the costs with making wrong choices, which contradicts the basic philosophy of the SMS approach. In later study,

Ready and Bishop (1991) explored that the MMM rule might yield inconsistent outcomes (e.g., for preservation or for economic development) depending upon the structure of the game against nature and suggested the MMR criterion instead. Because, MMR rule accounts for the cost of making the wrong choices unlike the MMM rule.

In this study, the decision maker chooses between prospects, where each prospect has two possible outcomes: maximum outcome (gain) and minimum outcome (loss). The decision maker knows the potential gains and losses of each alternative, but does not know the probabilities of occurrences of the gains and losses. Therefore, it is necessary to make some assumptions about the cost of being wrong (failure and receiving the minimum payoff), and the gain of being right (success and receiving the maximum payoff). The most frequently raised criticism against the MMM criterion to games against nature is that nature is not hostile, as is the opponent in a two-person game (Edwards, 1954). If one is ignorant about the probabilities, or has insufficient information about probability of the various outcomes or believes the information is irrelevant, and then he/she will simply assume outcomes are equally likely and calculate the average outcomes of each prospect, and compare them (Pažek & Rozman, 2009).

In general, subjects' anticipation of undesirable outcomes (overweighing the probability of bad events) - pessimism (see Chapman & Polkovnichenko, 2009); higher sensitivity to loss than to equivalent gain - loss aversion (see Kahneman & Tversky, 1979; Thaler & Johnson, 1990); and experience of initial negative outcomes - horns effect (Greaves & Ellison, 2011) etc. can increase their relative risk aversion, and favoring choices consistent with MMM criterion. Subjects could also learn from prior experiences and adapt to the situation while others could be myopic (Thaler & Johnson, 1990; Thaler*, et al.*, 1997). If a decision maker is myopic, according to (Thaler*, et al.*, 1997), he will first determine whether he likes the prospect of the initial gamble in the series, and if he concludes that he does not, and then he will consequently reject it in the entire series.

3. The Experiment: Incentivized Game

Participants: The participants in this experiment are farmers from two districts: Raya Azebo and Raya Alamata in Tigray regional state, north Ethiopia. We used the household name lists from the farm extension workers of the sub-districts to select the participants and conducted the experiment in 2016. Seven experienced and well-trained enumerators conducted the experiment on 394 farmers. The experiment on 358 subjects was conducted during the main survey, while the experiment on the other 36 participants was conducted during the pretest survey with the same instrument. The livelihoods of the people in the study area largely depend on subsistence small-scale agriculture. The frequency of drought seasons and other weather related risks in the country has been increasing in the last two decades. Traditional agricultural technologies, fragmented land, soil degradation, and heavy dependence on variable rainfall characterize agriculture in Ethiopia. The farmers, on the other hand, have low level of literacy, poor adaptive capacity and are vulnerable to extreme weather related risks.

This study draws on the design by Blackwell*, et al.* (2007) who used induced value experiment on campus students to assess how students make decisions under hard uncertainty and found majority of the participants make choices consistent to MMR criterion. In spite of the external validity concerns, the results from Blackwell*, et al.* (2007) reveal that no decision criteria is clearly superior under uncertain situations. Our study claims the reference points on the payment mode (context) also affects the nature of choices under uncertainty, which may have implications on technology adaption and climate change behaviors. Studying the decision-making behavior of non-standard subjects (farmers in the field) under uncertainty using real incentives (cash or field commodity) addresses external validity concerns. The results could complement the previous findings from campus students and increase our understanding of decision-making behavior under hard uncertainty.

Incentives: We paid the participants some incentive (real money) in Ethiopian Birr (ETB). The payment includes participation fee and performance-based fee. Participation fee is similar to all participants while the performance-based fee depends on participant's own performance from the subsequent choices of prospects they make during the game. The

participants received their payments at the end of the experiment and the payment varies depending on the outcomes their prospect choices.

We split the participants into two groups. Participants in one group receive their payments only in cash while the participants in the second group, if they pass the threshold limit, i.e., ETB 90 (At the PPP conversion factor on 31 December 2016, 1 USD=8.68 ETB), receive their payments in either cash or in-kind, depending on their choice. In this experiment, every participant under the in-kind treatment preferred receiving the in-kind commodity (a shovel) to its equivalent market price. However, the participants under the in-kind/cash payment treatment received shovel (as in-kind commodity) only if they pass the threshold limit and all of those who passed the limit took their payments in in-kind mode. The threshold, ETB 90, is set based on the wholesale market price of shovels in the regional capital city. Participants in the in-kind payment group who earn ETB 90 or more in the end can receive their payment either in cash, or in-kind and cash combination, while participants who earn less than ETB 90 in the five round choices receive their payment only in cash.

Procedure: The enumerators together with the extension workers in the community first ask the participants for their consent to participate in the experiment and play the games. The enumerators also tell the participants about the confidentiality of individual responses and that the aim is to learn about their decision-making behaviors. Once they get the participants' consent, the enumerators start explaining the procedures on the decision-making tasks. The enumerators tell to participants that they will participate in a set of choice activities where they would earn some money depending on their performance in the successive choice tasks. On the process, we excluded five participants who refuse to play the game because they thought it was a mere gambling and said their religion does not allow.

The two payment treatment modes, cash only or in-kind/cash, have similar uncertainty settings. The decision type applied in this experiment is a sequential game; i.e., participants play first by choosing the one prospect they prefer most among the three available alternatives, then nature plays. Each prospect available to participants has two possible outcomes while the probability of outcomes is unknown to them. One of the outcomes will result after nature selects the state of nature (either event A or event B).

The experiment proceeded by telling participants the following: "*Here, there are three available prospects each with two possible outcomes (maximum outcome and minimum outcome) following two events; Event A and Event B. The chance of either of these outcomes occurring is unknown. If you choose Prospect 1, then you will earn ETB 30 or ETB 15. If you choose Prospect 2, then you will earn ETB 40 or ETB 10. If you choose Prospect 3, then you will earn ETB 50 or ETB 3. The chance that ETB 30 occurs if you choose Prospect 1, the chance that ETB 40 occurs if you choose Prospect 2 and the chance ETB 50 occurs if you choose Prospect 3 are equal. So, which prospect do you choose?*" Figure 1 illustrates the procedure of decisions and the potential outcome for each choice.

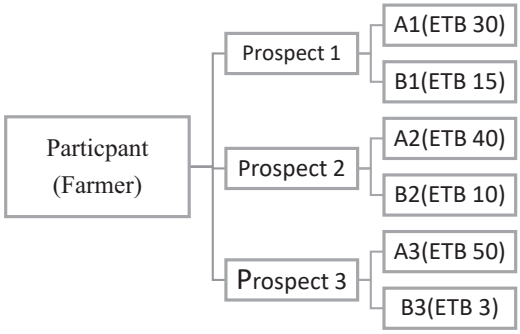


Figure 1: The decision procedure of the game played by the participants

The procedure is as follows. First, participants are asked to choose their most preferred prospect of all the available prospects. Then, they are asked to draw a ball from an opaque urn filled with unknown number of two types of colored balls: green and red colored balls. In so doing, the enumerators explain to the participants about the choice tasks by telling the correspondence between the colors of the balls and the payoffs of prospects. The numbers of green and red balls in the urn are unknown to the participants. The enumerators are told to make sure that the participants do not examine the balls in anyway. In the correspondence between the color of the ball drawn and the realized event, the green balls correspond to event A (maximum outcome of the chosen prospect), while the red balls correspond to event B (minimum outcome of the chosen prospect). From the point of view of the participant, who does not know the probability of neither event occurring, the situation is one of hard uncertainty (see Blackwell*, et al.*, 2007)

The enumerators started conducting the experiment after they explain the decision-making process to the participants, address questions from participants and make sure they understand the choice task. First, the enumerators ask each participant to choose their preferred prospect from the available prospects. Then, the enumerators ask the participants again to pick one color ball from the opaque urn to determine the outcome he/she receives. The participant receives the outcome of the prospect he/she has chosen corresponding to the color of the ball he/she picked. Each participant in both groups faces the same choice scenario, and makes the choice task for five consecutive rounds, one after another. We tell the participants the payoff they received in the previous rounds before they make a choice in the next round.

Experiment Task: The actual experiment starts with splitting the participants into two groups. Participants in one group receive their payment in cash only whereas the participants in the second group receive their payment as in-kind or cash, according to their own choice. The explanation of the setting is similar in the two groups. The probability representation is the same for the three prospects. The only difference between the three prospects is their maximum and minimum outcomes. Prospect 1 has maximum minimum payoff and matches to MMM criterion; prospect 2 has minimum regret and matches to MMR criterion, while prospect 3 has maximum expected outcome and matches to MEV criterion.

The participants make choices based on the risk of loss associated to the prospects. MMM criterion selects the safest option or a prospect that has maximum minimum outcome or minimum loss. Therefore, we expect the most risk averse participants to choose prospect 1. The MMM criterion selects the most conservative option available and does not account for the cost of making wrong choices. The MMR criterion accounts for the cost of making choices by selecting an option that minimizes the maximum opportunity loss (regret). Finally, prospect 3 has the maximum expected value outcome under equal probability assumption and corresponds to the MEV (Laplace) criterion. We expect that relatively more risk/loss averse subjects would apply MMM criterion, while the relatively less risk averse subjects would apply MMR or MEV criteria. Therefore, a transition of choices from MMM criterion to MMR or to MEV criteria reflects a reduction in risk aversion of subjects and an increase of choices of less conservative criteria. Generally, MMM rule is the most conservative of

decision rules and it chooses the safest option, while MMR rule, on the other hand, is more reasonable since it considers for the cost of making wrong choices and MEV rule is optimum and rational solution under equal probability assumption.

3.2. Theoretical Predictions

This paper considers three alternative decision criteria under uncertainty: MMM rule, MMR rule and MEV rule and tries to understand which criteria farmers prefer under uncertainty and examines factors that influence their choices of decision criteria. The three prospects have the same probability representations. The MMM decision criteria implied by prospect 1 has the maximum minimum value (ETB 15); min[Prospect 1] = ETB 15, min[Prospect 2] = ETB 10, min[Prospect 3] = ETB 3; max[min[Prospect 1], min[Prospect 2], min[Prospect 3]] = ETB 15. A participant who uses MEV decision criterion presupposes equal probabilities of each event occurring and selects the prospect with the highest average. In this case, Prospect 3 has the highest average (EV), i.e., EV(Prospect 1) = ETB 22.5; EV(Prospect 2) = ETB 25, EV(Prospect 3) = ETB 26.5. The MMM, MMR and MEV criteria are denoted by prospect 1, prospect 2 and prospect 3 respectively. The regret analysis is determined using the procedure in Table 1.

Table 1: Regret analysis and computations over prospects

Prospect	***Payoffs***				
		Best outcome	***Actual outcome***	***Regret***	***Maximum regret***
Prospect 1 (corresponds MMM)	Maximum	50	30	20	20
	Minimum	15	15	0	
Prospect 2 (corresponds MMR)	Maximum	50	40	10	10*
	Minimum	15	10	5	
Prospect 3 (corresponds MEV)	Maximum	50	50	0	12
	Minimum	15	3	12	

Note: * Indicates the minimum of the maximum regrets.

Table 1 shows that prospect 2 has the lowest maximum regret and is consitent to MMR criterion, where regret is a difference between the best possible outcomes, given nature's resolution of the uncertainty, and the outcome realized by the individual (Blackwell, et al.,

2007). Therefore, the choice of prospect 1 corresponds to the MMM criterion, prospect 2 to the MMR criterion, and the choice of prospect 3 corresponds to the MEV criterion.

To our knowledge, there is no similar empirical studies on smallholder farmers' choices under hard uncertainty. This study examines whether reward payment modes, repeated losses experience, learning and demographic factors like education influence farmers' choices of decision criteria. We test the following hypotheses:

i. Farmers use the most conservative decision criterion (MMM) or the safest option available to make their choices under uncertainty.
ii. Farmers do not make consistent choices of decision criteria under two different payments settings; i) the choice between in-kind and cash option if a threshold is passed versus cash-only payment.
iii. Learning and repeated loss experiences from earlier rounds influence choices in the later rounds.
iv. Age and education level of the farmers predict their choice of decision criteria.

To analyze the data and draw inferences regarding the observed behavior, we employed a multinomial logit (MNL) model. The dependent variable in this study is a choice of decision criterion, and it has three categories: MMM criterion (0), MMR criterion (1) and MEV criterion (2), where the numbers in parenthesis are the codes of categories. The baseline (reference) category is MMM, which is the most frequently chosen and the most conservative decision criterion that selects the minimum loss of all possible losses. The choice of the most conservative strategy is associated with a high degree of risk aversion, and the degree of risk aversion decreases from the MMM criterion to the MMR criterion, and from MMR criterion to MEV criterion. Therefore, if any explanatory variable takes a positive sign, it implies the variable increases the likelihood of farmer's choice of less conservative criteria and implies lower risk aversion, while negative sign implies a reduction of choices of less conservative criterion.

4. Results

4.1. Descriptive Statistics

Table 2 reports the definition and descriptive statistics of the variables, and expected effects of factors influencing choice of decision criteria including socioeconomic characteristics of participants. The paper includes payment mode, learning, and prior losses along with other socioeconomic explanatory variables in the model, and assesses whether they influence farmers' choice of decision criteria under uncertainty. The average age of subjects is 42.5 years. Looking at the literacy of subjects, about 63 percent have no literacy, 32 percent have primary education and 5 percent have secondary education or above. We expect relatively older farmers to be more risk averse and choose conservative strategies, whereas those with more education are less risk averse and choose less conservative strategies.

Table 2. Variable definitions, summary statistics (mean) and expected effects on choice of less conservative criteria.

Variable	Definition of variables	Mean	Expected Sign
Age	Age of the household head in years	42.5	-
Education	Education status of household head; 0= No education	0.627	
	"1"=primary education	0.32	+
	"2"=secondary education(+)	0.053	+
Household size	The number of individual members of the household	5.5	+
Farm size	The size of the farmland owned by the household (in hectare)	0.7	+
Livestock	The size of livestock owned by household in Tropical Livestock Units (TLU)	2.74	+
Expenditure	The average annual expenditure of households in ETB (in 31 December 2015, 1 USD=7.64 ETB)	20,890	+
In-kind	Payoff mode to subjects; 1: Choice if In-kind or cash, 0: Cash only	0.57	-
Loss	The percentage of subjects who earn a minimum payoff in the five rounds; minimum:1, maximum: 0;	0.46	-
Prior Loss_1	Percentage of subjects who earn a minimum payoff in the preceding round; Minimum:1, Maximum: 0;	0.51	-
Prior Loss_2	The percentage of subjects who earn a minimum payoff in the preceding two rounds in percent; Minimum:1, Maximum: 0;	0.49	-
Round (Learning)	The round of the choice task (1-5); converted to five dummy variables with first round as the "baseline (reference) category"		+
Decision	The principle farmers use to make choices (the dependent variable); MMM criterion		

criteria	(0), MMR criterion (1), and MEV criterion (2); with MMM as the baseline (reference) category

The average household size of the sampled households is approximately 5.5 members per household. Household size is a source of social capital, and this can reduce risk aversion and increase the likelihood of choosing less conservative rules. Farm size and livestock are proxies for household wealth and we use consumption expenditure to proxy household income and transform it into logarithm to include into MNL model. The advantage of using expenditure as indicator of household welfare is that expenditure fluctuates less than direct measures of income, which varies with harvesting periods in rural households. Besides, households easily reveal their expenditure than their income for different economic and psychological reasons. We expect income and wealth to reduce loss aversion and increase the likelihood of choosing less conservative strategy.

Reward type (payment mode) includes in-kind payment and in cash only payments. All subjects show higher valuation for the in-kind payment mode. The increase in (perceived) value of the payment is expected to increase loss aversion and reduce the likelihood of adopting less conservative criteria. Repeated experience of prior loss is also expected to increase loss aversion and reduce the likelihood of choosing less conservative criteria while an increase in subjects' experience of the choice tasks can reduce uncertainty, risk aversion and therefore, increase the likelihood of adopting less conservative criteria. We conduct statistical and econometric analysis to assess whether these explanatory variables explain the sources of variation for subjects' choices of criteria.

4.1.1. Choices of Decision Criteria

We conduct Pearson chi-square ($\chi 2$) test on proportions of farmers' choices of decision criteria in the five rounds. Table 3 reports standard $\chi 2$ tests and P-values for each series of rounds. The Pearson $\chi 2$ tests in Table 3 indicate that the participants did not choose randomly (H0: participants choose any strategy with probability 1/3; p-value < 0.01 for all scenarios) and the tests indicate that differences among the choice of three decision criteria are statistically significant except in the third round and that indicates choices of decision criteria is not random. Table 3 shows also the proportion of participants for each scenario in

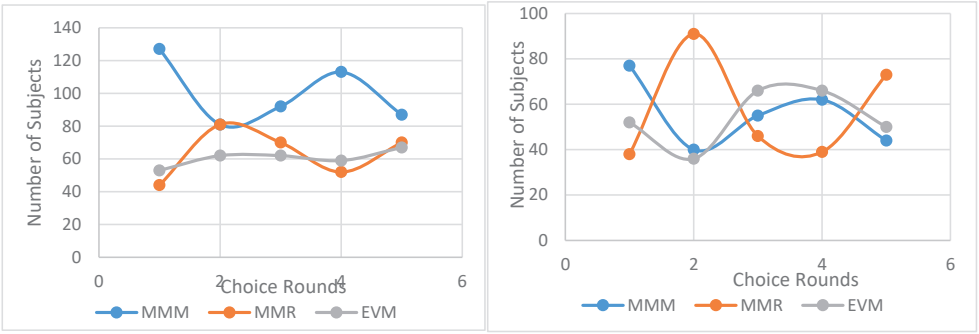
each of the five rounds farmers subjected to, and the overall choices of the farmers. The MMM, MMR and MEV criteria are the three categories of the dependent variable.

Table 3. Decision criteria adopted by subjects (frequency of responses, percentage and chi2/p* value)

	Decision Criteria				
Round	MMM	MMR	MEV	Total	chi2/p*
1	204	82	105	391	35.402
	26.22	13.58	18.32	20.00	0.000
2	121	172	98	391	39.749
	15.55	28.48	17.10	20.00	0.000
3	147	116	128	391	2.791
	18.89	19.21	22.34	20.00	1.000
4	175	91	125	391	13.392
	22.49	15.07	21.82	20.00	0.006
5	131	143	117	391	10.024
	16.84	23.68	20.42	20.00	0.033
Total	778	604	573	1955	
	100.00	100.00	100.00	100.00	

* Pearson chi2(2) / Bonferroni-adjusted p-values
Overall Test(s) of Significance:
Pearson chi2(8) = 81.0865 Pr = 0.000
likelihood-ratio chi2(8) = 80.0965 Pr = 0.000

Figure 2 displays choices made by subjects under cash only and in-kind treatments. It demonstrates that most participants make choices consistent with MMM criterion under the two payment modes. The dominance of choices consistent with the MMM criterion under the in-kind group persists to the end, while it descends and fluctuates under the cash only treatment. In the first round, 52 percent of the participants make choices consistent with the MMM criterion. More choices consistent with the MMM rule in the in-kind mode reflects high loss aversion of subjects. From this, we deduce that subjects value the in-kind commodity more than its equivalent market price and this increases their risk aversion. Figure 2 illustrates choices of subjects over the five rounds under the in-kind/cash or cash only payments.



i) Choices in in-kind payment ii) Choices in cash only payment

Figure 2: prospect choices of subjects over the five rounds

The fact that choices consistent with MMM criterion become superior to choices consistent to MMR and MEV criteria at the beginning reflects higher uncertainty aversion of subjects due to the lack of information. Different theories can explain subjects' choices of relatively high risk aversion: for instance, pessimism (see Chapman & Polkovnichenko, 2009); loss aversion (see Kahneman & Tversky, 1979; Thaler & Johnson, 1990) and ambiguity aversion (see Ellsberg, 1961). In the first round choice task, we believe subjects to have lowest information or highest uncertainty. This could be the reason most of the subjects adopt the most conservative strategy available. In the subsequent choices, where we presume subjects can learn and get more information from their experience of the earlier choice tasks, they start to shift away from the most conservative criterion and make choices consistent with the MMR or MEV criteria. Subjects learn from their own experience in the earlier choices, and this tends to reduce the uncertainty and their risk aversion.

4.2. Econometric Results

The descriptive statistics show differences of choice behaviors under cash only and in-kind/cash treatments and differences in choices of decision criteria in subsequent rounds. We employed MNL model to draw statistical conclusions regarding the observed behavior. We execute regression on reward treatment, experience, prior losses and socioeconomic factors to test the factors that influence subjects' choices of decision criteria under uncertainty. Table 2 presents the definition, mean and expected effects of variable while Table 3 presents the nature of distribution of choices decision criteria by the subjects.

4.3. Payment Mode, Learning and Choices of Criteria

Table 4 presents the results of the regression analysis from both a trimmed and extended model (including demographic variables). Models 1 of Table 4 presents results from a regression of choices of criteria on reward treatment (only cash vs in-kind) as an explanatory variable. The significant negative coefficient on reward type indicates that participants under the in-kind treatment make less choices consistent with the MMR and MEV criteria, and more choices consistent with MMM criterion. In other words, the in-kind treatment reduces the likelihood of making choices consistent with MMR and MEV criteria. Farmers revealed a high value for the in-kind payment mode, and this might increase choices consistent with the MMM rule. Under the in-kind payment option, the minimum amount of money participants should earn in the end in order to receive the in-kind reward is ETB 90. Therefore, the interpretation is that the risk of falling short of this threshold (reference point), to receive the in-kind payment, increases relative risk aversion and reduces choices of less conservative criteria. Kahneman and Tversky (1979) in their article on prospect theory argue that people are often risk averse for gains and risk seeking for losses. Franken*, et al.* (2006) further argue that whether individuals perceive the final consequence of their choices as a loss or as a gain depends on their point of reference.

This behavioral difference is consistent with our expectation. Despite the similar probability representations in both only cash mode and in-kind mode, more farmers make choices consistent with MMM criterion under the in-kind payment mode than they do under cash only payment. Subjects' loss aversion and risk aversion increase with the increase in stake value (Blackwell*, et al.*, 2007; Holt & Laury, 2002, 2005). Subjects' stronger preference to receive their payment in a shovel over cash reflects their higher perceived valuation for the shovel. This implies choice of decision criterion under uncertainty varies with variations in payment modalities.

Model 2 in Table 4 includes the variable "round" that reflects the learning or experience of subjects from the previous choice tasks as another explanatory variable along with variable in-kind reward payment. The result shows that round has significant and positive effect on subjects' choice of decision criteria. This implies that participants learn from the situation and adapt to it over time, and switch away from the most conservative MMM criterion

towards less conservative alternatives like MMR and MEV criteria. Therefore, learning reduces ambiguity and uncertainty aversion or it increases the likelihood of choosing less conservative choices. The supposition is that the degree of uncertainty is higher at the earlier rounds compared to the later rounds and it diminishes as subjects get more and more experience from the choices they make in the earlier rounds. Figure 2 also illustrates that prospect choices consistent with the MMM criterion is higher at the first choice round than in the subsequent choices tasks. The low experience of the game associated with high uncertainty and more choices consistent with the MMM criterion and vice versa is sensible. Controlling for reward type, prior loss experiences and socioeconomic factors, the increase in participants' experience of the choice task increases choices consistent with MMR criterion.

We expect learning to increase the likelihood of farmers making choices consistent with MMR and MEV criteria, and drifting away from MMM criterion. This implies that subjects tend to adopt less conservative criteria in the later choice rounds compared to earlier rounds when they have little information and learning. The explanation for this is that uncertainty is a complicating factor, which farmers with less experience and lower education try to avoid. An experimental study by Butler and Loomes (2011) reported that even most literate and numerate individuals cannot easily articulate and state their preferences. Studies in social and cognitive psychology have also been devoted to demonstrating that human judgment is imperfect (Kerr, *et al.*, 1996). Kerr, *et al.* (1996) further explain that such imperfections often constitute more than random fluctuations and deviations from what is rational, prescribed, or ideal judgments. While strategic thinking is limited, behavior can approximate equilibrium predictions if individuals can learn over time or through imitation or some other adaptive process (Camerer, 2003). Decisions made in the absence of feedback and opportunities for learning often differ from decisions made in settings that allow feedback and learning. Choices made under repetitive markets often converge toward the rational choice equilibrium (Vlaev, 2018). Similarly, the subjects in this study tend to make choices consistent with the MMR and MEV criteria, i.e. choices that account for the cost of making wrong choices and are prescribed as optimal or rational criteria under the equal probability assumption, respectively.

Table 4: Estimation of multinomial logit models (where the dependent variable is decision criteria and Minimax is a reference category), coefficient and t statistics (in parentheses).

MMR=1	Model 1	Model 2	Model 3	Model 4
In-kind	-0.488***	-0.490***	-0.547***	-0.504***
	(-4.41)	(-4.42)	(-3.03)	(-2.59)
Round		0.0947**	0.751***	0.756***
		(2.45)	(4.20)	(4.21)
2_Prior Los			-0.342	-0.354**
			(-1.92)	(-1.97)
3_Prior Loss			-0.144	-0.162
			(-0.81)	(-0.90)
Primary education				-0.00186
				(-0.01)
Secondary education(+)				0.841*
				(1.80)
Age				0.00326
				(0.41)
Household size				0.0559
				(1.17)
Livestock				-0.101
				(-0.43)
Farm size				0.168
				(1.04)
Constant	0.0319	-0.249	-3.111***	-3.772***
	(0.38)	(-1.75)	(-3.76)	(-3.83)
MEV=1				
In-kind	-0.472***	-0.546**		-0.530**
	(-4.20)	(-3.09)		(-2.78)
Round		0.235		0.243
		(1.35)		(1.38)
2_Prior Loss		-0.318*		-0.343**
		(-1.82)		(-1.95)
3_Prior Loss		-0.0565		-0.0509
		(-0.32)		(-0.29)
Primary education				-0.226
				(-1.12)
Secondary education+				0.782*
				(1.74)
Age				-0.00805
				(-1.01)
Family size				0.0782*
				(1.64)
Livestock				-0.251
				(-1.08)
Farm size				0.109
				(0.69)
Constant	-0.0292	-0.785		-0.866
	(-0.34)	(-0.98)		(-0.91)
Observations	1955	782		782

Notes: ***, ** and * denotes significant at the 1, 5 and 10 % level; respectively.

In Model 3 of Table 4, we include prior losses (i.e., 1 if the subject receives minimum outcome, and 0 otherwise) to test whether it influences subjects' choice of decision criteria under uncertainty. Standard economic theory suggests that examining the value of prospects exclusively and without considering prior outcomes. However, decision makers are influenced by the prior losses they experience (Thaler & Johnson, 1990). The results in Model 3 show that the coefficient on prior losses is significant and negative. This implies that farmers' experience of repeated losses from the previous rounds reduces their likelihood of making choices consistent with MMR and MEV criteria in the later rounds. This means subjects who experience losses twice or more in the previous choices tasks are more likely to make conservative choices and reduce risk of losses. Therefore, subjects react to the losses they experience in the prior rounds by adopting more conservative criterion to reduce losses in the subsequent rounds. On a study of myopic behavior, Thaler, *et al.* (1997) explained myopic loss aversion using two behavioral principles: loss aversion and mental accounting. Loss aversion implies that decision makers tend to be more sensitive to losses while mental accounting states that decision makers who frame their decisions in some ways will tend to make short-term rather than long-term choices. Other studies (e.g., Franken, *et al.*, 2006; Tversky & Kahneman, 1992) examine the effects of prior loss and reference points on risk aversion. Counterevidence by Franken, *et al.* (2006) argue that subjects who experience prior loses make riskier choices than participants who experience prior gains.

In the end, we include socioeconomic characteristics to test whether choices of decision criteria vary across subjects. Model 4 of Table 4 shows that the coefficient on secondary education or above is positive and significant although at the 10 percent significance level. When only socioeconomic factors are included, secondary education or above has significant effect at the 5 percent significance level. This implies that farmers with secondary education or above make more choices consistent with less conservative criteria, i.e. the MMR and MEV criteria. This might be because secondary education or above enables subjects to understand the complexity of the choice tasks, and hence reduces their risk aversion. Consistent with our results, Rosen, *et al.* (2003) showed that individuals with some years of college education have a more risk taking attitude. Other studies (e.g., Bar-Shira, *et al.*, 1997; Hartog, *et al.*, 2002) similarly demonstrated that years of schooling significantly reduce risk aversion.

5. Conclusions

Using framed field experiment with real incentives on smallholder farmers in north Ethiopia, we examine how they make choices under hard uncertainty like in a game against nature. We split farmers into two groups. Farmers in one group receive their payments only in cash; while farmers in the second group, if their payoff passes a threshold limit of ETB 90, can choose between receiving their payment as in-kind or in cash. The farmers in both groups do not know the probability of the outcomes, but make choices in five rounds. The results show that the choices of farmers under hard uncertainty are not arbitrary, but no decision criterion consistently dominate the choices in the consecutive choice rounds under the two payment modes. When the subjects have no experience with the choices and thus uncertainty is high, the majority of them make choices consistent with the minimax criterion, which has the minimum loss. Learning through the experience from choices made in earlier rounds reduces uncertainty, and increases choices that match with minimax regret and expected value maximizing criteria. In contrast, choices consistent with the minimax criterion dominate under in-kind payments compared to choices under cash only payments. Farmers' higher perceived valuation of the in-kind payment, and their strive for passing the threshold in payoffs to be able to choose the shovel, might induce them to be loss averse and use the minimax criterion. The results also indicate that farmers with secondary education or above make more choices that minimizes maximum opportunity loss, and choices that maximize expected value.

These results have important implications for the design of policy programs to enhance technology adoptions in uncertain agricultural environments. First, the negative effect of the in-kind payment mode suggests that potential losses of high (valuable) outcomes reduces the likelihood of adopting more promising and optimal technologies. The fact that more farmers make choices that minimize the maximum loss under the in-kind payment implies that introducing mechanisms to minimize the risk of losses (and avoid them from falling below the subsistence level), and sharing the burden of losses through insurance schemes can induce farmers to adopt reasonable strategies and optimal technologies. Second, the positive effect of education and learning or experience implies that one should introduce technologies selectively to the most educated farmers first, as they are more open to new

technologies. Through the effect of learning, technologies will then diffuse easier to the rest of the farmers. Exhibitions of technologies, where farmers can learn and understand from the process could also facilitate farmers' adoption of promising and optimal strategies and technologies that improves farm productivity.

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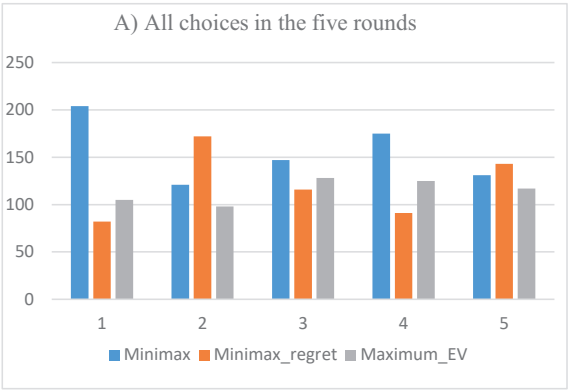
Appendix

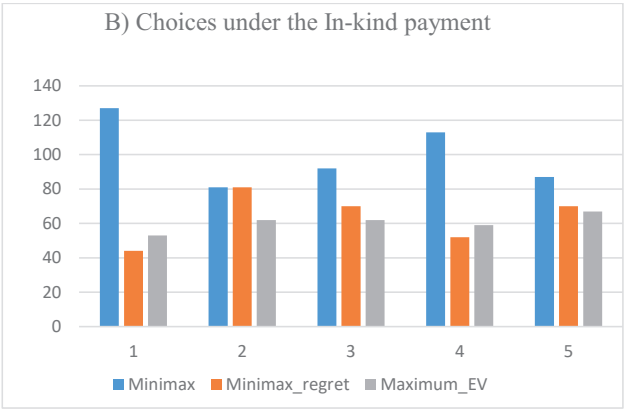
Table A-1: Results of Multinomial logit models only with socioeconomic factors (Model 1) and including Payment mode and round (Model2) with choice of decision criteria dependent variable and minimax base category (standard errors in parentheses). Minimax (MMM) criterion is a baseline category, MMR refers to minimax regret criterion and MEV refers Maximum expected value.

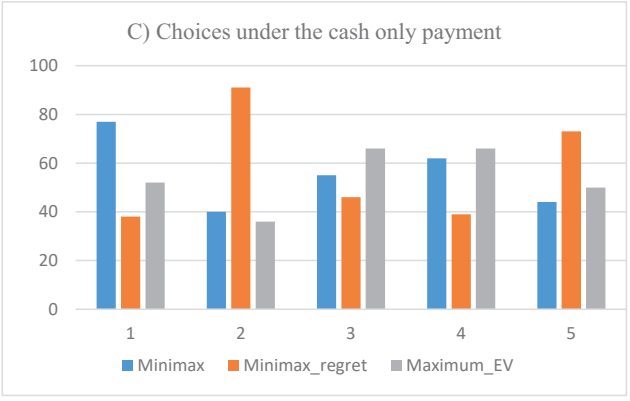
	Model 1 b/se	Model 2 b/se
MMR=1		
age	0.002	-0.001
	(0.01)	(0.01)
Primary school	-0.095	-0.133
	(0.13)	(0.13)
Secondary school	0.734*	0.482
	(0.30)	(0.31)
Household size	0.057	0.036
	(0.03)	(0.03)
Livestock	0.042	0.002
	(0.19)	(0.19)
Farm_size	0.040	0.093
	(0.10)	(0.10)
Gender	0.315	0.258
	(0.33)	(0.33)
Married	-0.097	-0.125
	(0.15)	(0.16)
Expenditure	-0.062	0.001
	(0.12)	(0.12)
In_kind		-0.471***
		(0.13)
Round		0.095*
		(0.04)
Constant	-0.054	-0.409
	(1.11)	(1.12)
MEV=1		
Age	0.005	0.002
	(0.01)	(0.01)
Primary school	-0.085	-0.123
	(0.14)	(0.14)
Secondary school	1.024***	0.773*
	(0.29)	(0.30)
Household size	0.103**	0.081*
	(0.03)	(0.03)
Livestock	0.007	-0.032
	(0.19)	(0.20)
Farm size	-0.113	-0.057
	(0.10)	(0.10)
Gender	0.593	0.535
	(0.31)	(0.31)
Married	-0.023	-0.051
	(0.15)	(0.15)
Expenditure	-0.074	-0.012
	(0.12)	(0.12)
In-kind		-0.469***
		(0.13)
Round		0.082*
		(0.04)
Constant	-0.220	-0.525
	(1.12)	(1.14)

Notes: ***, ** and * denotes significant at the 1, 5 and 10 % level; respectively.

Figure A-1: Prospect choices of subjects over the five rounds







Do Farmers in Developing Countries Value River Ecosystem Services improvements? A Choice Experiment of Ethiopian Farmers´ Adoption of Sustainable Management Strategies[3]

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Abstract

This study explores Ethiopian farmers' propensity to adopt sustainable management strategies to rehabilitate small rivers and streams in terms of practices that improve ecological conditions but also have positive impacts on the provisioning ecosystem services (ES) generated by their agricultural activities. In order to map their preferences for particular river ES and management strategies, we conducted a discrete choice experiment of different management strategies to improve reliability of water supply, flood protection walls, riparian vegetation and water quality in nearby rivers. Farmers have heterogeneous preferences, but significant and positive demand for the improvements of these ES. Households with larger farms and better access to irrigation are willing to pay more for water supply reliability. Households with farm plots nearby a river are willing to pay more for flood protection services, and households engaged in bee-keeping activities are willing to pay more for regeneration of riparian vegetation. The results show that households are willing to pay more for ES attributes particularly associated with the provisioning services provided by their farming. These findings can be used to design pathways out of poverty and at the same time secure sustainable use of ES in developing countries.

Key words: Provisioning Services; Preference heterogeneity; Motivation crowding; Agriculture

JEL classification : Q15 ; Q2 ; Q51 ; Q57

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1. Introduction

The livelihood of Ethiopian households depend heavily on rain-fed agriculture. The increasing demand for water because of the recurrent droughts and unpredictable rainfall along with the ongoing land degradation, deforestation and soil erosion bring the need for a sustainable land management to the forefront. The Millennium Ecosystem Assessment (2005) classifies agricultural food production as "provisioning services" dependent primarily on the inputs provided by nature. Even if sustainable management of rivers are beneficial to society, farmers could care only about river attributes directly related to their farming. Birol*, et al.* (2010) examined preferences for environmental services of farmers, who derive both direct use and option values from irrigation water from rivers, and preferences of local residents who derive indirect use values from locally produced vegetables and non-use values from improved ecological status. They found that both groups have significant and positive benefits, but different preferences. Although ecosystem services (ES) studies in developing countries so far has focused on the link between provisioning services and poverty alleviation, a considerable gap remains in understanding how pathways out of poverty may be achieved based on the sustainable utilization of ES (Suich*, et al.*, 2015). We conducted a choice experiment (CE) in order to examine the willingness to pay (WTP) of Ethiopian farmers for restoration and improvement of groundwater banking (river water supply), flood protection walls, riparian vegetation and water quality in nearby rivers; and explore the preference heterogeneity among the farmers.

The provisioning services in agriculture and human well-being strongly depend on ES inputs. This study presents information about the ecological benefits of restoring the river ES attributes that are largely public goods, and benefit the broader community. We expect that farmers with irrigable farmland would benefit from the improved water supply reliability, farmers engaged in beekeeping activity would benefit from regeneration of riparian vegetation, and those who have farm plots near the river benefit from improved flood protection walls. Evidences show that the effectiveness of economic incentives to address biodiversity protection remains contested, and sometimes are counterproductive or less effective than would be predicted assuming entirely self-interested individuals (Bowles & Polania-Reyes, 2012; Evans*, et al.*, 2013; Frey & Oberholzer-Gee, 1997; Frey & Stutzer, 2006).

We are, however, not aware of any systematic study on the association between the agricultural provisioning services and household preferences for particular river ecosystem attributes.

This study aims to understand the nature of farmers' preferences for river ES attributes, and identify factors that influence their preferences for particular attributes. Preferences often tend to exhibit heterogeneity either based on personal characteristics, environment characteristics (Shi*, et al.*, 2016), cultural background and different ways of life (Zander & Straton, 2010), or spatial factors (Brouwer*, et al.*, 2010; Franceschinis*, et al.*, 2016). This study examines the role of agricultural provisioning services on inducing preference heterogeneity among the farmers. In exploring the sources of preference heterogeneity, we include individual and farm related variables such as farm size, distance of their plots to a river, participation in beekeeping activities, and access to irrigation as shifters of mean WTP values for the ES attributes. We interpret the effects of farm related variables in relation to the anticipated changes of provisioning services in agriculture. Analyzing individual heterogeneity reduces biases in the parameter estimates (Hensher & Greene, 2003; Hensher*, et al.*, 2005), and gives more information for better prescriptions of policies that include equity considerations (Birol*, et al.*, 2006). For example, considering the effect of distance decay in WTP is important in calculating aggregate WTP of the affected population for use in e.g. Cost-Benefit analysis; both when using primary valuation studies and in benefit transfer exercises (Schaafsma*, et al.*, 2012).

We analyze the data using a mixed logit model. The methodological tests show that a mixed logit model with correlation is superior to other alternative models. The results show that households have significant positive WTP for ES improvements in nearby rivers. The mean WTP of households for the four attributes is about ETB 1697 per year, which is about 8 percent of their reported annual household expenditures. Households are willing to pay the most for the improvements of flood protection walls and water quality in the nearby rivers. Preferences for all the ES attributes exhibit heterogeneity, but farmers have stronger preferences for river ecosystem attributes that increase the provisioning service of agriculture at their own farm (in terms of increased crop yield and/or reduced risk of crop losses). Households with farm plots far from the river reveal weaker preferences for

improving the flooding protection services, households with large farm size and better access to irrigation reveal stronger preferences for river water supply reliability; and households engaged in bee-keeping activity reveal stronger preferences for improving conditions for riparian vegetation. The findings suggest that the improvements in agricultural provisioning services associated with the improvement of the ecological conditions of rivers can create the right kind of incentive for farmers to participate in sustainable land management, and make farmers both the stewards and beneficiaries of improved ecosystem services.

2. The Choice Experiment survey

2.1. Study area, Sampling method and Survey design

The sampled households are residents in the rural areas of Raya Alamata and Raya Azebo districts in the Tigray region in north Ethiopia. It is about 600 KM north of Addis Ababa, the capital of Ethiopia and 160 KM south of Mekelle, the capital of the regional state of Tigray. According to the most recent Ethiopian Central Statistical Agency census report (CSA, 2007), there were 32,360 households in Raya Alamata and 20,532 households in Raya Azebo. The proportion of sampled households from the two districts, i.e., about 60 percent from Raya Azebo and 40 percent from Raya Alamata, corresponds to the proportion of the population data from the districts. We selected 358 sample households using proportional and systematic random sampling from household name lists. Districts and villages with larger population get higher quotas.

The livelihood of households in the study area depends on rain-fed agriculture. In general, Ethiopia has seen frequent variability of river flow and fewer normal years, and more years of drought and flooding (Siam & Eltahir, 2017). The incidence of rainfall variability (drought and flooding) in the region is also higher and becomes a challenge for agriculture and environmental conservation. The Ethiopian Ministry of Water Resources initiated an irrigation development study in the Raya valley (i.e. the study area) in 2008, aiming for optimal utilization of groundwater for irrigation as the area has fertile soils and high agricultural potential. Sustainable management and rehabilitation measures around rivers and streams can enhance the provision of ecosystem services and farmers will benefit,

directly or indirectly, from the improvements of river water supply reliability, flooding protection, riparian vegetation and water quality.

We conducted pre-test surveys in April and May 2016 in four villages in the study area. In the first exploratory survey, we used a structured questionnaire and carried out face-to-face (f2f) interviews with informed village communities and local agriculture and development extension agents in the study area. The survey instrument design process included discussions with key informants, experts from Mekelle University, focus groups, and series of pretests. The focus group discussants and informant interviewees regarded the four ES attributes to be important to them and to the community. In a pre-test survey, we tested the questionnaire on a broad range of respondents in order to reflect the variation we expected to see in the final survey sample, checked whether respondents understood the questionnaire, and kept refining and clarifying attributes using reports and opinions from discussants to make it easier to understand.

Table 1: Fieldwork stages.

Stage	Research activity	Period	Description	Purpose
1.	Literature review and semi-structured interviews with key stakeholders in the area	March-April 2016	Identification of potential factors of high influence over the area	Identify relevant attributes to include in the CE study
2.	Exploratory survey (N>20 face-to-face interviews) and pre-testing.	April-May 2016	Characterization of social perceptions towards factors of change and ESs	Identify and refine relevant attributes to include in the CE study
3	Pre-test survey (N =36 face-to-face interviews)	May 2016	Ask questions with the attributes and scenarios in the last survey instrument	Check whether the questions are understandable to respondents
4.	Main Survey (N = 358 face-to-face interviews)	May-August 2016	Assess preferences of the local people towards different land management scenarios	Conduct the CE exercise with the selected attributes

The pretest of 36 respondents was conducted in May 2016, and the results were used to developed final instrument for the main survey. Finally, we translated the questionnaire into the local language (Tigrigna).

In the pretest, the respondents reported difficulty in grasping the Choice Experiment (CE) choice tasks with three new alternatives and five attributes. Therefore, we changed the choice task to choose between two new alternatives and an opt-out option in the final survey. The choice set comprised unlabeled alternatives: "Alternative A" and "Alternative B", and the opt-out alternative (i.e. “do nothing”/status quo at zero additional cost). Each respondent faced a sequence of eight choice sets from which to choose his or her most preferred alternative. Well-trained and experienced enumerators conducted the f2f interviews of the respondents, which were household heads. We conducted the final survey from May to August 2016. No respondent protested against the program in the choice experiment, and all respondents completed the full questionnaire.

2.2. Definitions of Attributes and Attribute Levels

The assignment of economic values to ES requires an understanding of how changes in ES affect social wellbeing. People benefit from a multitude of ES provided by nature: provisioning, regulating and cultural services. In the pretest, we included the following four attributes in the CE: protected forest area in hectare, riparian vegetation, invasive species and water quality. We asked respondents during the pretest whether these attributes were relevant to the community, and which other ecosystem attributes we should include instead or in addition. They mentioned the alarming decline of river water supply (water amount) and the seasonal flooding as serious problems to the community, and suggested that these should be included. As a result, we used the following four ecosystem attributes in the main survey: i) river water supply, ii) flood protection walls, iii) riparian vegetation, and iv) water quality. Table 2 presents the final set of attributes, their levels, and what type of ES they represent.

Table 2: Choice Experiments attributes, their associated Ecosystem Service (ES) type and levels. The respondents were told that the deterioration in quality and quantity of ES (the status quo measures) is what they would experience in 10-15 years. The attribute levels in bold and italics represent the "Opt Out/Do nothing option" delivered at zero additional cost (termed Alternative C in the Choice sets; see Figure 1).

Attribute	Ecosystem Service Type	Description	Attribute Levels
Water supply	Provisioning	The reliability of water supply for use of irrigation and other domestic activities	***Do nothing (30 % loss),*** 200 ha (5 % loss), 400 ha (10 % increase)
Flood walls (Protection)	Regulating	A barrier on the river channel designed to contain the river water, which may rise to unusual levels during seasonal or extreme weather events.	***No protection,*** Stonewall, Gabion wall
Riparian Vegetation	Cultural	The condition of plant habitats and species diversity along the river margins and banks	***Poor,*** Moderate, Good
Water Quality	Provisioning	The suitability of water quality for domestic and household activities	***Bad,*** Same as today, Better
Extra Cost in Ethiopian Birr (ETB)		The extra cost of conservation (as an environmental tax) per Household per Year	***ETB 0***, 100, 300, 600, 800

Note: The Purchasing Power Parity (PPP) Adjusted Exchange rate (Dec 31st 2016) is 1 USD=8.68 ETB.

Below we describe each of the ES attributes in more detail.

Water supply: This attribute is associated with provisioning services, and refers to the reliability of river water supply for irrigation and domestic activities. Groundwater banking measures such as construction of dams, diversions, reservoirs and catchments to reduce water runoff during raining periods will recharge and improve the reliability of water supply on rivers. We informed the respondents that some hectare (ha) of grazing land will be retired (i.e., set aside from grazing and other human uses) for construction of groundwater banking to boost the river water supply. This attribute has three levels: 10 percent increase in river water supply (with 400 ha retired land), 5 percent decline in river water (with 200 ha retired land), and 30 percent losses in river water supply in 10 to 15 years associated with doing

nothing. Farmers who have access to irrigable land will directly benefit more from rivers water supply reliability.

Flood Protection walls: This attribute is associated with regulating services, and refers to the improvement of the resilience of riverside walls to flooding. In addition to improved resilience to flooding, better protection measures can enhance the rehabilitation of previously degraded land. This attribute has three levels: Gabion-wall, Stonewall and no wall (no flood protection measure). "Gabion-wall" is associated with high flooding resilience, and restoration of part of previously degraded arable land. "Stonewall" is associated with moderate flooding resilience, and retains only the current arable land area. Without improved flood protection measures, the current incidence of flooding and degradation of arable land and pasture land will persist. Therefore, we assume farmers who have farm plots near rivers can benefit more from improved flood protection.

Riparian vegetation: This is associated with cultural services, and refers to the improvement of the condition of riparian vegetation, i.e. the vegetation along the riverbanks. These vegetation corridors are important for recreational services, the scenery of rivers, and the existence values of species in these corridors. This attribute has three levels: poor (continued loss of species), moderate (maintaining the current species) and good (regeneration of 10 percent of locally extinct species). Reports show that some species are currently locally extinct. The riparian vegetation can provide food and shelter for birds, and nectars for bees. Therefore, we assume farmers engaged in beekeeping will directly benefit more from vegetation improvements.

Water Quality: This attribute is associated with provisioning services and refers to the improvements in the suitability of water quality for drinking, cooking and washing, and irrigation. The new management strategies either preserve or improve the current water quality. The water quality attribute has three levels: Good (suitable for all uses), same quality as today (i.e. the water needs treatment to be suitable for drinking and cooking), and bad quality (not suitable for drinking, but for irrigation only). The description of this attribute is partially similar to the description by Andreopoulos*, et al.* (2015).

Extra Conservation Costs (EC): This refers to the annual payments in Ethiopian birr (ETB) that the household would have to pay for the implementation of the proposed management measures if the majority of households agreed with the management proposal. We specify the payment vehicle under an environmental tax scheme. Households in the pretest surveys reported that separating environmental tax from land tax would make it easier to monitor whether the program spend the money exclusively on the proposed management plan. The respondents are told that they could elect trustees from the village administrators or village chiefs, if they want, to monitor whether the program spends the money on the proposed management program only. The cost attribute is used as the denominator for expressing welfare changes, and enables the calculation of marginal WTP for the changes in each of the ES attributes. We also informed the respondents that the absence of conservation measures has no additional monetary cost, but would imply up to 30 percent loss of river water supply, continued flooding damages on farmland and pastureland, poor water quality and continuing local extinction of plants and animal species in 10 to 15 years' time.

The survey instrument includes information about the current condition of the river, the projected climate change impacts, and the management strategies to restore the ES around the river. This gives respondents a common context to base their responses on. We also told them that without improved management measures to mitigate the adverse impacts, climate change would have negative effects on the provision of ES from the river and the local environment. In order to make the attribute levels (look) realistic, we consulted experts in natural sciences at the Rural and Landscape Development Departments at the Mekelle University as well as development extension workers in the study area. We also told respondents that the decision would be implemented if the majority of the respondents accepted the conservation program. This can increase consequentiality and reduce the potential hypothetical bias in choice experiments.

2.3. Experimental Design

Choice experiments combine Lancastrian characteristics theory of value (Lancaster, 1966) and McFadden's random utility theory (McFadden, 1973). The Lancastrian characteristics theory of value dissects the good into attributes and presumes that consumers reap the

utility of the good from its characteristics, and not from the good itself; while McFadden's random utility theory assumes that an individual chooses the option which maximizes her/his underlying utility function. The indirect utility function is:

$$U_{ijt} = \beta'_i X_{ijt} + \in_{ijt} \quad (1)$$

Where X_{ijt} is a vector of observable attributes, β_i is a corresponding vector of utility coefficients that vary randomly over people, and $\in_{ijt}$ is a random term that represents unobserved component of utility. The vector X_{ijt} can include $0/1$ terms to allow for alternative specific constants (ASC), and for attribute levels and individual specific variables. The inclusion of ASC captures the average effect of various components such as the endowment effect, status quo bias, omission bias, unobserved attributes and the impacts of complexity such as the fatigue effects (Boxall*, et al.*, 2009; Meyerhoff & Liebe, 2009) etc. The inclusion of demographic and farm related factors of individual agents can account for the preference heterogeneity which is due to observable factors (Hanley*, et al.*, 1998).

The CE places respondents in a situation where they have to make trade-offs between attributes of the good, and this gives more information. The superior information advantage in CE comes at the cost of considerable cognitive burden on the respondents (Meyerhoff & Liebe, 2009; Scarpa*, et al.*, 2007). To minimize the choice complexities and cognitive burden of respondents, we create only two new alternatives, each with four ES attributes. The alternatives are unlabeled and have generic titles (Alternative 'A', Alternative 'B' and Alternative 'C'(Opt out)). Figure 1 illustrates an example of a choice set in the final survey. Bekker-Grob*, et al.* (2010) found that unlabeled designs increase respondents' attention towards attributes, and are therefore more suitable for examining trade-offs between attributes. The inclusion of an 'opt out' option reflects unconditional demand (Greiner*, et al.*, 2014), and is important in order to get a true measure of welfare (Boxall*, et al.*, 2009; Veldwijk*, et al.*, 2014).

Which of the following land management scenarios do you favor? "Alternative A" and "Alternative B" would entail cost to your household. No payment would be required for the for Opt-out option, but the conditions at and around the rivers would deteriorate to low levels for water supply, water quality, riparian vegetation and flood protection.			
Attributes	Alternative Scenario A	Alternative Scenario B	Alternative C Opt-Out (No conservation)
Water Supply	200 ha (5 % loss)	400 ha (10 % increase)	30 % loss
Flood protection walls	Gabion wall	Stonewall	No protection
Riparian Vegetation	Regenerate	Retain the present	Poor
Water quality	Good	Same as Today	Bad
Extra Cost /HH/ year	ETB 600	ETB 300	0
I would prefer:	Alternative A _____	Alternative B ____	Neither ____

Note: ETB = Ethiopian birr; at the PPP conversion factor on 31 December 2016, 1 USD=8.68 ETB.
Figure 1: An example of a choice set /choice card, as it was presented to the respondents.

The CE design here applies the orthogonal main effect design (OMED), and executes R codes to generate the choice profiles, blocks and choice sets. The OMED comprises 32 pairwise comparisons of alternative ES attributes, which generated 16 choice sets grouped in two blocks having eight choice sets each. OMED is important in isolating the effects of individual attributes on choice of alternatives, and avoids the shortcoming of revealed preference in which attributes are often found to be correlated (Hanley, *et al.*, 1998). The alternatives differ from one another in the levels one or more of their attributes assume. In creating choices, we imposed restriction to ensure the new alternative has at least one attributes that is better than the "opt out" option, in order to avoid presenting an alternative that has poor ES levels but a higher price.

2.4. Mixed Logit Model

A Mixed logit model (MIXL) is the extension of the Multinomial Logit (MNL) model, and captures unobserved heterogeneity by allowing (some of) the parameters of the utility function to vary according to assumed distributions considering that a respondent makes choices in more than one choice situation (Train, 2003). It can also be further specified to handle panel data so that random parameters vary over individuals (and not observations)

in order to examine interpersonal heterogeneity. The MIXL model assumes the error term to be identically and independently distributed (iid) extreme value type I. From a parametric heterogeneity distribution that describes how preferences vary in the population, it is possible to derive conditional estimates of the parameters at the individual-level (McFadden & Train, 2000; Train, 2009). The random utility of individual i from alternative *j* for choice occasion *t* is:

$$L_{ijt}(\beta_i) = \frac{e^{X_{ijt}\beta'_i}}{\sum e^{X_{ijt}\beta_i}} \quad (2)$$

The coefficients of each person β_i is observable, but varies over the people. The cumulative density function of β_i in the population is $f(\beta_i/\theta)$; where, θ is the parameter of this distribution. The distribution can be continuous or discrete, while different elements in β may follow different distributions (including some being fixed), and the elements of β may be correlated with each other (Hess & Train, 2017). It is also possible to accommodate observed heterogeneity (deterministic taste variation) in the random parameter by including individual specific covariates. Therefore, the vector of random coefficients is:

$$\beta_i = \beta + \emptyset Z_i + \eta_i \quad (3)$$

Where Z_i is a set of socioeconomic characteristics that influence the mean of preference parameters; $\emptyset$ is a KxM matrix of additional parameters. Fiebig*, et al.* (2010) stated that the generalized multinomial logit (G-MNL) model is a more generalized version of the MIXL model that allows scale heterogeneity. On the contrary, Hess and Train (2017) demonstrated that: (i) the MIXL model allows for all forms of correlation including scale heterogeneity; (ii) the G-MNL model is a restricted form of the MIXL model which, with appropriate implementation, can allow for scale heterogeneity, but not other sources of correlation; (iii) none of the models disentangles scale heterogeneity from other sources of correlation; and (iv) models that assume that the only source of correlation is scale heterogeneity; do necessarily capture, in the estimated scale heterogeneity, whatever other sources exist. The individual and farm related factors that may affect the variation of utility are included in the MIXL specification. These individual specific factors do not vary across alternatives, and hence their interaction with ASC is included.

The fundamental econometric problem in CEs is calculating the WTP of individuals for a change in attributes of the goods or services under investigation. Based on the estimated parameters on ES attributes and the cost attribute, it is possible to calculate the WTP estimates. The value of a marginal change in any of the attributes often known as "implicit prices" is expressed as a ratio of coefficients of any of the non-monetary attributes to the coefficient on the cost attribute. The linearity assumption is considered in random utility models, and this enables the estimation of marginal utilities and marginal WTP (Hanemann, 1989). Most commonly, the distribution of WTP for an attribute is derived from the distribution of the ratio of individual coefficients. The distribution of cost coefficient plays a major role in the distribution of WTP since it enters as a denominator.

3. Results and Discussion

3.1. Descriptive statistics of socioeconomic characteristics

We mapped the socioeconomic characteristics of sampled households in order to examine the sources of preference heterogeneity among the households. Table 3 reports the descriptive statistics of the socioeconomic characteristics of the sampled respondents. Variables such as age, education, household size, farm size and distance of the plot to the river are continuous variables; whereas residence, beekeeping and irrigation participation are categorical. The average number of years of formal education is 1.8, and this reflects the low level of literacy in the study area. CSA (2007) reported that the literacy rate in the study area is 8.4 percent for Raya Azebo and 14.8 percent for Raya Alamata. This is lower than 15.7 %, which is the average of the southern zone of Tigray regional state. The average household size in the study area is 4.2 individuals per household, which is low compared to the average household sizes of the sampled households of 5.7 individuals.

Table 3 also reports the expected signs of the variables in terms of their expected effect on household WTP for improving the provision of river ES attributes. We assume that improved provision of river ecosystem attributes is associated with increasing the provisioning services of agriculture (i.e. increased agricultural productivity and a reduction of crop losses). Therefore, we expect that older people are less likely to pay for the conservation

program mainly because of two reasons. First, the deterioration of river ecosystem services without the conservation program would take place in 10-15 years, and this long-term orientation of the conservation activity would decrease the disposition of older people. Second, older people may be less open to changes in general. In contrast, education is supposed to increase the propensity of individuals to accept new management measures. We use household expenditures as a proxy for income, and thus we expect WTP to increase with annual expenditures of the household. Farmer's access to irrigation can increase income, and hence WTP for improved river water supply reliability. This can enhance farm productivity, and ecological conditions in the local community. We also expect the increase in farm size, access to irrigation farming and beekeeping activities to increase (positively affect) the WTP for the conservation programs. In contrast, farm plots far from river streams may be less vulnerable to flooding problems, and this lowers the WTP of households for construction of improved floodwalls.

Table 3: Definition and descriptive statistics of demographic and farm characteristics); mean value and the expected sign in terms of the effect on willingness-to-pay (WTP). N =358 households.

Variable	**Definition**	**Mean**	**Expected Sign**
Age	Age of the household head (in years)	43.2	-
Household size	The number of family members in the household	5.7	+
Education	Education level of the household head (in years)	1.8	+
Livestock	The average livestock owned by the household (in Tropical Livestock Units (TLU))	2.7	+
Expenditures	The average annual expenditure of households (in ETB/ household/year)	20,890	+
Raya Alamata	The district of residence of households (1=Raya Alamata; 0 =Raya Azebo)	0.4	-
Farm size	The area of farm plot the household owned (in Timad)	2.9	+
Irrigable Land	Whether the household owns irrigable land; (0 = No; 1 = Yes)	0.44	+
Beekeeping	Whether the household engaged in beekeeping or honey production; (0=No, 1=Yes)	0.19	+
Distance	The distance of the farm plot from the river; walking time in minutes	19.2	-

Notes: PPP-corrected exchange rate 2016, 1 USD=8.68 ETB; 1 hectare= 4 Timad

3.2. Econometric Results

This study employed the generalized multinomial logit or "gmnl" package in the R software to estimate random parameter logit (RPL) models with observed and unobserved heterogeneity across individuals. Unobserved heterogeneity is modeled by allowing the parameters to vary randomly over individuals according to a continuous or discrete or mixture distribution, chosen a *priori* by the researcher (Sarrias & Daziano, 2015). The package also enables the computation of individual conditional estimates of random parameters and WTP measures. The package consolidates the Multinomial logit (MNL) model and its extensions into a single R package. We first estimate a standard MNL model, and then go on to RPL model variants that relax the IIA restrictions. Then, we *examine and compare the* goodness of fit of models using *Akaike information criteria (AIC), Bayesian information criteria (BIC) and log-likelihood ratios (LR).* I*nformation criteria enable us to* examine both nested and non-nested models.

Table 4 reports the AIC, BIC and LR estimates of the MNL model, mixed logit model with correlated alternatives (MIXL) and mixed logit model without correlation (MIXLU). We also conducted methodological tests on the distribution of random parameters and model specifications. The LR test shows that the MIXL model is superior to MIXLU model when we regress it only with the attributes, but the effect of correlations among the alternatives ceases to be significant when we include socioeconomic factors as mean shifting variables of the random parameters. We set the coefficients on the four ES attributes; water supply, flooding protection, riparian vegetation and water quality to be random coefficients, while the cost coefficient is set as a non-random parameter so that we can interpret the effects of attribute changes as monetary values. We use the normal distribution assumption for the random coefficients, because the lognormal and censored distributions reduce the log-likelihood value.

Table 4 presents the mixed logit model results, with and without socioeconomic characteristics. We find that the estimated coefficients for all the ES attributes and ASC are significant and positive. This implies that the ES attributes significantly explain the behavior of farmers when confronted with choice sets that include these attributes. We also tested the

scale heterogeneity of estimates, in a scaled-multinomial logit model, and it turned out to be insignificant. Because of this, the discussion henceforth focuses on the results from the MIXL model. We include demographic and farm characteristics to find the source of preference heterogeneity among households.

Table 4: Parameter estimates (standard error in parentheses) for the MNL, MIXLU and MIXL models #

	MNL	MIXLU	MIXL	MIXL_H
ASC	2.115***	2.674***	3.203***	2.777***
	(0.129)	(0.171)	(0.191)	(0.234)
Water supply	0.438***	0.731***	0.701***	1.058***
	(0.063)	(0.102)	(0.088)	(0.375)
Flood protection	1.036***	1.776***	1.743***	1.574***
	(0.067)	(0.153)	(0.157)	(0.359)
Riparian vegetaion	0.740***	1.016***	0.917***	1.091***
	(0.060)	(0.115)	(0.099)	(0.239)
Water quality	0.769***	1.136***	1.405***	2.352***
	(0.067)	(0.150)	(0.174)	(0.542)
Extra conservation cost	-0.204***	-0.298***	-0.272***	-0.296***
	(0.012)	(0.018)	(0.016)	(0.022)
Water supply.AGE				-0.019**
				(0.008)
Water supply.EDUCATION				0.052
				(0.033)
Water supply.FARMSIZE				0.119**
				(0.055)
Water supplys.IRREG_LAND				0.431**
				(0.185)
Flood protection.FARMSIZE				0.123 *
				(0.070)
Flood protection.RESIDENCE				0.370
				(0.258)
Flood protection.DISTANCE				-0.456 *
				(0.254)
Riparian vegetaion.BEEPKEEP				0.114***
				(0.037)
Riparian vegetaion.FARMSIZE				-0.021
				(0.055)
Riparian vegetaion.EDUCATION				-0.119
				(0.259)
Water quality.AGE				-0.024**
				(0.009)
Water quality.HOUSEHOLDSIZE				0.031
				(0.047)
Water quality.IRRIGABLE LAND				0.004
				(0.242)
N	2854	2854	2854	2822
Log-likelihood	-1899.441	-1762.356	-1701.855	-1826.110
BIC	3846.621	3604.278	3531.013	3882.631
AIC	3810.882	3544.713	3435.709	3710.220

Notes: Asterisks (, **, ***) denote significance at 10%, 5 %, and 1% level, respectively.*

 # MNL is multinomial logit model, MIXLU is mixed logit model without correlation, MIXL is mixed logit models with correlation between random parameters, and MIXL_H mixed logit models with heterogeneity explaining factors respectively.

The positive signs of the coefficients of the ES attributes indicate the positive effects of attribute improvements on household welfare. The changes are from 5 percent loss to 10% increment in water supply in 10 to 15 years, from fair water quality to good and potable quality, from Stonewall to Gabion wall flooding protection, and from retaining today's riverside vegetation to regeneration of 10 percent of currently locally extinct species. The high levels of ES attributes encompass the moderate levels of ES attributes, and hence giving a larger value to high improvements in attribute levels, as expected from economic theory.

The significant positive coefficient on ASC indicates that, all else being equal, the respondents prefer the new conservation alternatives to the current situation. Almost all (96.7 percent) of the respondents in the final survey chose the new alternative measures; alternative A or alternative B. Five respondents chose the opt-out option in seven out of eight choice sets offered to them. Choices of opt-out option accounts for only 3.3 percent of the total number of responses. Nobody protested against the proposed conservation program. This might be because respondents consider the ES attributes to be relevant to the community, which again is probably the result of careful pretesting. Some studies (e.g., Adamowicz*, et al.*, 2005) show that respondents are less likely to choose the opt-out option under 2-alternatives CEs compared to 3-alternatives CEs. The use of only two new alternatives in this study may partly cause the respondents' to ignore the opt-out option. In estimating the parameters from CE application, Bennett and Blamey (2001) suggest the inclusion of ASC, and they state that it controls for the average effect of systematic and unobserved information related to why respondents tend to select a particular alternative in each CE question. Some of the previous CEs (e.g., Botzen & van den Bergh, 2012; Cadavid & Ando, 2013) did not consider the effect of ASC in their models. The WTP estimates for environmental goods also vary according to whether ASC is included or not. Therefore, CE studies should report whether the process of parameters estimation and/or WTP calculations considered the ASC, and interpret results accordingly.

3.2.1. Estimation of Willingness to Pay

The estimated coefficients for the attributes in CE applications are not directly interpretable, but the ratio of the coefficient of each of the non-monetary attributes to the coefficient for

the cost attribute gives the WTP value for a marginal change in each of the attributes. We compute the WTP values for marginal changes in ES; see table 5, based on the estimated parameters on ES attributes and the cost attribute from MIXL and MIXL_H models in table 4. The results show significant and positive WTP of the smallholder farm households for ES improvements around the nearby rivers. The total WTP of all four ES attributes make up from about 8 to more than 10 percent of their current annual household expenditure (which can be seen as a proxy of household income); as estimated from the MIXL and MIXL_H models, respectively. This demonstrates that rural households in developing countries can have significant WTP for improving the provision of ES of the nearby rivers. Vollmer, *et al.* (2013) also found significant positive demand for improved river ecology in a choice experiment among urban households in a developing country context (i.e. Indonesia).

Table 5: The mean WTP per household per year; in ETB (1 USD= 8.68 ETB at the PPP adjust ed exchange rate on 31 December 2016) for changes in ES attributes; estimated from the M IXL and MIXL_H specifications.

Attributes	WTP Estimates from MIXL
Water supply	240
Flood protection	638
Riparian Vegetation	312
Water Quality	508
Total WTP for the four ES attributes	1698
ASC	1,165
Total sum (WTP)	***2863***

We first discuss the WTP estimates from the MIXL model in table 5. The demand for improved reliability of water supply is consistently significant and positive, and it indicates that rural households have positive demand for a reliable water supply on their nearby rivers. Table 5 shows that households are willing to pay, on average, ETB 240 annually for a 10 percent increase in supply of river water for irrigation and domestic uses. This is about one percent of their annual household expenditure, whereas they are willing to pay more than two percent of their average annual household expenditure (ETB 508) for improving the river water quality. Table 5 shows that households on average are willing to pay the least

for the increase in water supply from nearby rivers compared to their WTP for other ES attributes; perhaps because of the associated parcel of grazing land that will be retired from any human use. Thus, this results could be due to the specification of the attribute and its levels, but it is supported by e.g. a CE study by Latinopoulos (2014) that examined public preferences for water supply services in Greece, and found households to have higher WTP for drinking water quality improvements than for avoiding interruptions in water services.

Since improving existing drinking water supply services in developing countries depends crucially on available financial resources, investment decisions to improve the efficiency and sustainability of future water services should be based on the understanding of public preferences and values. Our results show that households have a significant positive demand for improved water supply and water quality in their nearby rivers despite their income constraints. However, households seem to reveal even stronger preferences for improved water quality. Tarfasa and Brouwer (2013) pointed out that the demand for more reliable water services in Ethiopia is high and rapidly growing, and in a CE, households were willing to pay up to 80% extra for improved water supply over and above their current bills. Similarly, Abramson*, et al.* (2011) studied rural water service improvements in developing countries and showed significant WTP for improvements in water quality and quantity.

The MIXL results in table 5 also shows that households, not surprisingly, have the highest mean WTP for improving the flood protection walls along the rivers (ETB 638 per year), as flood protection walls can reduce the risk of crop losses and damages of arable land. Households are willing to pay about three percent of their annual household expenditure for improving the flood protection services, and thus avoid the degradation of farmlands. The stronger preference of households for improved flood protections walls than for improved water supply could arise because of loss aversion, i.e. that they could be more sensitive to losses than to similar gains, and/or that the expected losses here are larger than the gain from improved water supply. We also find that households with larger farms and with farm plots closer to a river are willing to pay more for flood protection walls.

Households are also willing to pay ETB 311 per household for improvements of riparian condition; equivalent to about 1.5 percent of household's total annual expenditure. The

regeneration of riparian vegetation has a wide range of benefits including provision of food and shelter to some animals, purification of water and recreation and aesthetic services; and the relatively large WTP estimate for these ES indicate these services are clearly recognized by these farm households.

The MIXL_H results in table 4 also show significant positive WTP for all ES attributes, but here WTP is highest for water quality followed by flood protection, riparian vegetation and water supply. The total annual WTP per household for all ES attributes is somewhat higher than from the MIXL model. Since the WTP estimates from the MIXL_H model varies with the socioeconomic factors included to explaining the variation in random parameters across farmers, we use the WTP estimates from MIXL model.

On average, the MIXL model results show that households are willing to pay ETB 1698 in total per year, i.e., about 8 percent of their annual expenditure, for improved water supply reliability, flood protection, riparian vegetation and water quality on their nearby rivers. The total WTP of households including the ASC (ETB 1165) becomes ETB 2863; and this amounts to 14 percent of their annual household expenditure. The total number of households, according to the 1994 population and housing census, in the two districts of the study area is 52,892 (32,360 households in Raya Azebo and 20,532 households in Raya Alamata districts). Therefore, the aggregate WTP values of households for the four ES attributes is ETB 104,091,456 (1698 x 52892) per year, and the total WTP value including the ASC is ETB 151,429,796 (2863 x 52892). The aggregate WTP estimates suggest the presence of substantial demand by rural households for the improvements of river ES in developing countries. However, it should be noted that presence of preference heterogeneity among the households for the ES attributes (see table A-2 in the Appendix) may bias direct aggregation of individual WTP values (especially if the sample is not representative on the characteristics that lead to heterogeneity in the population of farmers).

These aggregated benefits of measures to improve these ES of rivers, could then be compared to the costs of different measures in a benefit-cost analysis of measures. Data on the local costs of these measures and their effects are, however, scarce. We have found some cost estimates for the flood protection and other measures, and they indicate that benefits in

our case could exceed the costs. In Ethiopia, gabions are produced by several medium-sized enterprises, and they are used for soil and water conservation purposes. On average, the cost for 1 m3 of gabion basket in Ethiopia is approximately ETB 335 (Nyssen*, et al.*, 2016). Nyssen*, et al.* (2016) added that the local community often provided free labor to conservation practices to protect their villages and their farmlands, but the cost for stone collection to fill inside 1 m3 gabion basket is approximately ETB 90. Similarly, a 50-m3 gabion check dam costs ETB 16,750 for the gabions and ETB 4,500 for labor. Similarly, Nyssen*, et al.* (2016) also examine Log-dams as alternative to gabion check-dams on ephemeral streams and pointed out that fig tree seedling had started growing in the channel bed at the foot of Log dam, indicating improvements of moisture conditions on the following dry season. In a study in northern Ethiopian highlands, Frankl*, et al.* (2013) stated that the installation of check dams reduced the sedimentation at the cross-sectional areas of the gully channels by an average of 33.5%. Similarly, Bombino*, et al.* (2006) examined the effects of check-dams on riparian vegetation in the Mediterranean environment pointed out that the groundwater table has raised and showed high potential for ecological restoration in the months after the rainy season, provided livestock is kept out of the gully.

3.2.2. Preference Heterogeneity and Provisioning services

Column 4 (MIXL_H) in table 4 presents the parameter estimates for the four ES attributes including the household and farm related variables that can explain observed heterogeneity. The standard errors of standard deviations for the estimated random parameters are statistically significant, which indicates that preferences are heterogeneous among the households. We include age, education level, farm size, livestock, plot distance from a river, irrigable land and beekeeping to test if they explain the heterogeneity in farmers' preference for ES. Rolfe*, et al.* (2000) and Nahuelhual*, et al.* (2004) pointed out that the inclusion of socioeconomic factors is a simple and decisive way to estimate a more accurate model of choice. The interaction of household and farm related variables with the ASC attribute is included in MIXL model to test whether they can explain the preference heterogeneity, because these variables remain the same for a given respondent regardless of what he or she chooses in all choice questions.

The coefficient on the age of the household head is significant and negative in all specifications. The interpretation is that households with relatively older household heads are less receptive to new conservation measures, and hence increasing age reduces the WTP of households. This is consistent with our expectation, and also consistent with Bacon (1912), who in his essay "Of Youth and Age", stated that young people are fitter to invent than to judge, fitter for execution than for counsel, and fitter for new projects than for settled business and pursue new management of actions which they have chanced upon. The other reason for the negative effect of age on WTP can be that the CE survey informed the respondents that the deterioration of ES around rivers without improved conservation activities will happen in 10-15 years of time. This long-term orientation of the conservation practices may reduce the interest of older household heads, and make them discount the future benefits (provisioning services in agriculture) more than the youths do, and hence reduces their WTP.

The coefficient on access to irrigation and farm size included in river water supply are significant and positive, implying that households with larger farm size and better access to irrigation are more willing to pay for improvement of water supply. This can be due to two reasons. First, the expected benefit from a more reliable river water supply is higher for those households who have large farm size and irrigable land. Second, large share of household income in developing countries comes from farming those households with larger farm size and irrigable land might have higher income, and economic theory predicts higher WTP for environmental goods and ecosystem services with higher income (see McConnell (1997)).

The preferences for improved riparian conditions also exhibit heterogeneity among households. The results show that household's engagement in beekeeping activities increases their WTP for improved riparian vegetation conditions. This might result from the expectation that their bees can easily get nectar from the restored riparian vegetation, and this can increase honey production. Households engaged in bee keeping activities might also develop some sense of positive sentiments to forests because they know bees generally benefit from forests. Table 4 also reports that education has no significant effect on

household's preference for riparian vegetation, but in a related study, Aklin*, et al.* (2013) examined the effect of income and education on environmental preferences in Brazil and found only secondary education as an important determining factor (which very few have in our sample).

Similarly, the results show that households reveal stronger preferences for the improvements of flood protection services than for other river ES attributes. The preferences also exhibit heterogeneity, and we test whether farm size, place of residence and plot distance from a river explain the heterogeneity in preferences for improved flood protection services. The coefficient on the plot distance is significant at 10 percent level and negative, while the coefficient of farm size is significant at 10 percent and positive. Households with larger farm size are willing to pay more for improvements of flood protection walls, while households with farm plots far from the river streams are willing to pay less. The negative effect of distance may be because the farm plots at a distant from the rivers are less vulnerable to flood risks, and have lower risk of crop loss from flooding. The positive effect of farm size might be due to the fact that the expected benefit from improved flood protection or reduced risk of crop loss from flooding on large farms is higher than on small farms. Therefore, the significant effects of farm related factors implies that the increase in the provisioning services farmers expect to generate in farming, resulting from improved ecological conditions, explain observed preferences heterogeneities among the households. Thus, farmers reveal significant positive demand for improved river ES, but have stronger preferences for attributes that increase the provisioning services in their farm.

To sum up, households in developing countries have substantial preferences for river ES improvements and stronger preferences for flood protection services and water quality improvements. Preferences for the ES also exhibit heterogeneity among the households, and the provisioning services associated with the improvements of ES around rivers explain preference heterogeneity. Thus, balancing the goal of improved natural environment against other *desirata*, such as increased income is not just a problem of allocating scare resources towards competing ends. With right kind of mechanisms, farmers can become both the stewards and beneficiaries of improved ecosystem services. Preference heterogeneity

observed across the choice attributes in this CE suggests that policy makers should take this into account when designing PES schemes and allocating resources, in order to improve the implementation of ES improving measures.

4. Conclusions

We conducted a choice experiment on north Ethiopian farmers to evaluate their preferences for river ecosystem services improvements, and explore factors motivating their preferences. This study contributes to the CE literature in a developing country context, and adds evidence that farmers have significant and positive willingness to pay (WTP) for improvements in water supply, flood protection walls, riparian vegetation and water quality in their nearby rivers. The estimated mean WTP of households for the four attributes combined ranges from ETB 1698 to ETB 2023 per year, which is about 8 to 10 percent of the annual household expenditure. The results also show that farmers exhibit the highest demand for the improvements of flood protection services and water quality improvements. This suggests that conservation programs should give priority to flood protection services and water quality improvements.

The preferences for ES also demonstrate heterogeneity among the farmers, and it is important to consider it when aggregating the WTP estimates. We include farm related and individual variables as mean shifting variables to test whether they explain observed preference heterogeneity among farmers. Households with larger farm size and access to irrigation are willing to pay more for the improvements of river water supply, and households engaged in beekeeping activities are willing to pay more for regeneration of riparian vegetation. Households with larger farm size are willing to pay more for improvements of flood protection services, while households with farm plots at distant from the river are willing to pay less. The results suggest that the variation provisioning services associated with river ES improvements induce the preference heterogeneity across households. Therefore, with proper coordination of incentives and management strategies, farmers can become the main stewards and beneficiaries of ecosystem services.

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Appendices

Table A-1: Results of Multinomial logit (MNL) model, Simulated Multinomial logit (S-MNL) model, Mixed logit model with correlated alternatives (MIXL), Mixed logit model without correlation (MIXLU) and generalized multinomial logit (G-MNL) model

	MNL	S-MNL	MIXLU	MIXL	G-MNL
ASC	2.115***	3.337***	2.674***	3.203***	12.148***
	(0.129)	(0.568)	(0.171)	(0.191)	(2.114)
Water Supply	0.438***	0.503***	0.731***	0.701***	0.990***
	(0.063)	(0.084)	(0.102)	(0.088)	(0.206)
Flood Protection	1.036***	1.323***	1.776***	1.743***	2.429***
	(0.067)	(0.135)	(0.153)	(0.157)	(0.420)
Riparian vegetation	0.740***	0.879***	1.016***	0.917***	1.590***
	(0.060)	(0.093)	(0.115)	(0.099)	(0.375)
Water Quality	0.769***	1.005***	1.136***	1.404***	1.742***
	(0.067)	(0.117)	(0.150)	(0.174)	(0.376)
Extra Cost	-0.204***	-0.249***	-0.298***	-0.272***	-0.445***
	(0.012)	(0.023)	(0.018)	(0.016)	(0.077)
tau		0.663***			0.955***
		(0.122)			(0.143)
					(1.346)
gamma					-0.305*
					(0.141)
N	2854	2854	2854	2854	2854
Log-likelihood	-1899.441	-1890.400	-1762.356	-1701.855	-1622.457
BIC	3846.621	3836.496	3604.278	3531.013	3348.349
AIC	3810.882	3794.801	3544.713	3435.709	3270.915

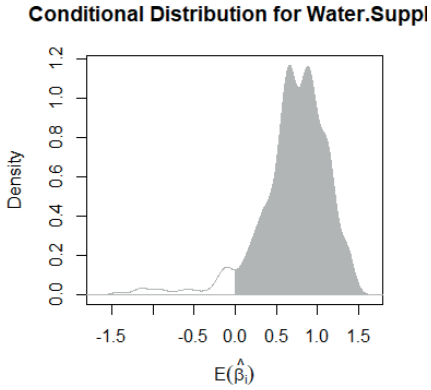
Standard error in parenthesis. Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table A-2: Standard deviations of the random parameters from MIXL model results

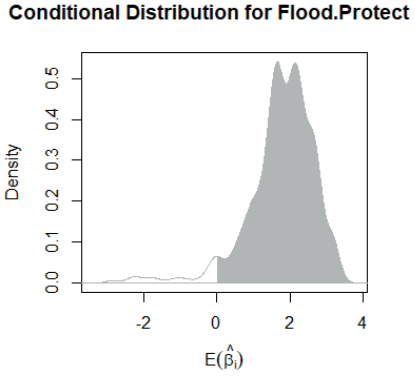
	Estimate	Std. Error	z-value	Pr(>|z|)
Water Supply	0.62931	0.13313	4.7269	2.280e-06 ***
Flood Protection	1.35928	0.17267	7.8721	3.553e-15 ***
Riparian vegetation	0.99435	0.14198	7.0034	2.499e-12 ***
Water Quality	1.93605	0.18275	10.5940	< 2.2e-16 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

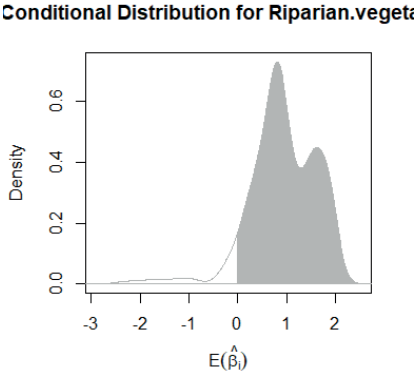
Figure A-1: the distribution of the individuals' conditional mean for the parameters of water supply, flood protection, riparian vegetation and water quality attributes (the grey area displays the proportion of individual with positive conditional mean).



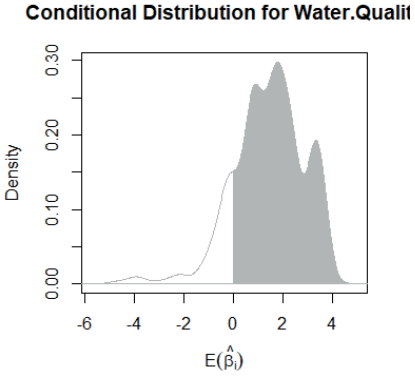
a) Kernel density for wate supply



b) Kernel density for flood protection



c) Kernel density for riaprian vegetation



d) Kernel density for wate quality

"Not my cup of coffee":

Farmers' Preferences for Coffee Variety Traits - Lessons for Crop Breeding in the Age of Climate Change[4]

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Abstract

The advent of biotechnology and conservation of genetic resources hold the utmost promise to improve traits to meet the growing demand for increased crop production during climate change. While previous studies and national policies focus narrowly on yield improvements, farmers' adoption of improved crop varieties remain less than desirable from an economic and social point of view. Developing new varieties by integrating traits of high demand by farmers and making them available might increase farmers' adoption of new varieties. This study aims to inform breeding priority setting by examining farmers' preferences for coffee traits. Choice experiments are applied on smallholder farmers in northern Ethiopia to map their preferences for improvements of four coffee attributes: i) yield, ii) weather tolerance, iii) disease resistance and iv) the maturity period. The traits are important to the farmers for their choice of a variety, and they exhibit strong preferences for weather tolerant and disease resistant varieties. Thus, they prefer yield stability more than high yielding or early maturing varieties. Education, access to irrigation and farmer's experience in coffee farming significantly explain the preference heterogeneity among farmers. These results suggest that breeding programs should give priority to yield stability in order to increase farmers' adoption of new varieties*;* and thus secure *in situ* preservation of these traits while increasing farm productivity in the age of climate change. These findings also suggest that *ex situ* conservation programs should give priority to early maturing and high yielding varieties that the farmers do not give priority to maintain in their own fields, in order to conserve the coffee genetic resources of Ethiopia and build climate resilience.

Keywords: Coffee; Traits; Crop Breeding; Climate Change; Choice experiment
JEL Classifications : Q18 ; Q51 ; Q55 ; Q57

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1. Introduction

Coffee is grown by 20-25 million families in more than 80 tropical and subtropical countries (Bacon, 2005; Vega*, et al.*, 2003), and Arabica coffee accounts for two-third of the global coffee market. Meeting the growing demand for increased production while safeguarding the genetic biodiversity of coffee is, however, a great challenge for policy makers. The advent of biotechnology and conservation of genetic resources hold the utmost promise to improve phenotypes of high economic importance and bring socially desirable outcomes. However, policy makers to a large extent narrowly focus on evaluating the importance of high yield varieties, while farmers' adoption of the new variety technology is low (e.g., Dalton, 2004; Shiferaw, et al., 2014; Zeng, et al., 2014). Evidences from multi-attribute crop studies in developing countries showed that farmers have stronger preferences for drought tolerant crops (Asrat, et al., 2010; Kassie, et al., 2017).

Climate change is threatening global coffee yields as changing temperatures and rainfall patterns affect plant growth. The changing climate may also be leaving coffee plants more vulnerable to diseases. Thus, in the age of climate change it is important to conserve the genetic diversity in high Arabica coffee diversity countries like Ethiopia, as this genetic pool is likely to improve the possibilities for adapting coffee growing to future climates and secure the livelihood of smallholder coffee farmers in developing countries.

This paper aims at increasing our understanding of Ethiopian smallholder farmers' preferences for Arabica coffee traits, and suggest how this knowledge could be used to construct breeding programs for coffee varieties farmers are likely to adopt, and thus conserve *in-situ.* For example, if farmers have strong preferences for high yield traits, they are more likely to maintain such varieties in their farmed fields. However, the farmers would then be less likely to cultivate or maintain other coffee varieties with lower yields, but with traits like drought tolerance that could critically affect the future ability to adapt to climate change. In order to preserve these traits *ex-situ* conservation efforts would be needed to supplement on the farm (*in situ*) conservation.

While previous studies have examined trait preferences of Ethiopia smallholder farmers for annual crops like teff (*Eragrostis abyssinica*) and sorghum (Asrat*, et al.*, 2010), and found environmental adaptability and yield stability to be important, very little is known about the trait preferences of farmers for perennials like coffee. This paper seeks to answer the following questions. 1) Which traits of Arabica coffee varieties do smallholder farmers wish to cultivate the most? 2) Are there trait preference variations among the farmers? 3) Which observable factors explain the variations in farmers' preference for coffee traits? We employ choice experiments (CEs) to elicit farmers´ preferences and willingness- to-pay (WTP) for improvements in the following traits of Arabica coffee: yield per hectare, weather tolerance, diseases resistance, and the maturity period. We also explore the preference heterogeneities among the smallholder farmers, and the sources of heterogeneity, as this in general is found to be important for targeted communication programs, differentiated product offerings, market segments and market niches (Allenby & Rossi, 1999). Thus, the results from this study can be used in the dissemination and adoption of improved coffee varieties.

We find that farmers have strong preferences for improvements in yield stability manifested in stronger preferences for weather tolerant and disease resistant traits than for high yielding and early maturing traits of Arabica coffee. The results show that the attribute preferences of farmers exhibit significant heterogeneity. We include socio-economic factors to explain sources of variations in the preferences for the coffee attributes. Farmers with experience on coffee farming have stronger preferences for high yield trait, but weaker for early maturing traits. On the other hand, farmers with access to irrigable farmland have weaker preferences for weather tolerant coffee traits. Farmers with more years of education have stronger preference for early maturing traits, but weaker preferences for diseases resistant traits. Policy makers aiming at technology dissemination and coffee breeding programs should thus give priority to disease resistant and weather tolerant traits. Developing new varieties by integrating traits in demand by the farmers, tailoring the improved variety technologies to the preference categories, and making them available to meet these demands, will increase farmers' adoption of improved new varieties. The findings also suggest that *ex-situ* conservation programs should complement the on-farm, *in-situ*, conservation by giving more emphasis to traits less preferred by farmers.

The paper is organized as follows. The next section discusses the background of coffee production in Ethiopia. Section 3 describes the data collection and explains the choice experiment and survey design. Section 4 presents and discusses the results from mixed logit model, while section 5 concludes.

2. Coffee Production System in Ethiopia

Ethiopia is a home of origin and diversity for Arabica coffee species (Teressa*, et al.*, 2010), and Ethiopian people have a history of drinking and enjoying coffee for over 1,000 years (Bertrand*, et al.*, 2005; Waldvogel, 2003). Ethiopia is one of the world's largest coffee producing countries and the single country known to harbor a wide range of coffee genetic diversity in a diverse array of coffee farming systems. There are more than 5,000 varieties of Arabica coffee in the country (Tsegaye*, et al.*, 2014), and they can still be found growing wild or semi-wild in the undergrowth of tropical highland forests. Ethiopian foreign exchange earning largely depends on coffee export. There are four main coffee farming practices in Ethiopia: i) forest coffee, accounting for 8-10 % of the production, semi-forest coffee (30-35 %), garden coffee (50-57 %) and plantations (5 %)(Kufa, 2012). Thus, 95 % of the total coffee produced can be attributed to smallholder farmers.

The productivity of coffee in the forest coffee and semi-forest coffee farming is about 200-500 Kg per hectare, which is lower than the national average productivity (600 -700 Kg per hectare). The coffee species in the forests and farms vary in productivity per hectare, appearance and internal genetic structure (López-Gartner*, et al.*, 2009). Meeting the growing demand for increased production while safeguarding the genetic diversity of coffee is a great challenge for policy makers. The advent of biotechnology and conservation of genetic resources hold the utmost promise to improve phenotypes of high economic importance, and bring socially desirable outcomes. The presence of vast genetic variability in *Coffea arabica* genotypes of Ethiopia creates the opportunity to create coffee varieties, through selection and hybridization, with good yield performance, resistance to major diseases, and distinct quality characters.

Previous studies and policies on annual crops narrowly focus on evaluating the benefits of high yielding varieties, but farmers' adoption of these improved varieties is low (e.g., Dalton, 2004; Shiferaw, et al., 2014; Zeng, et al., 2014). Evidences from multi-attribute crop studies in developing countries show that farmers have stronger preferences for drought tolerant than for high yielding crops (Asrat, et al., 2010; Kassie, et al., 2017). However, these studies examined the farmers' preferences for crop varieties such as "teff"and maize. In contrast, coffee is arguably more robust to weather shocks than annual crops, but the practice of coffee farming is more challenging because of less possibilities for inter-annual agronomic adjustments and long lasting effects of farming decisions as well as the ecological importance of preserving genetic diversity.

Farmers focus on their private economic benefits, and select and cultivate coffee varieties based on the benefits they obtain and/or expect to obtain from a particular trait (Hein & Gatzweiler, 2006). Farmers' emphasis on adoption of high yield coffee varieties could also accelerate the erosion of coffee genetic diversity in the forests and the semi-forest coffee farms. The changes in the market price of coffee and substitute cash crops like Khat, coffee diseases, and extreme weather variability etc. in the region aggravate the erosion of coffee genetic diversity. In coping with the environmental stressors, farmers' selection of coffee varieties to cultivate and maintain on their farm along with natural processes over generations of cultivation shapes the genetic structure of coffee (Baidu-Forson*, et al.*, 1997; Smale*, et al.*, 2001). Farmers' interest in increasing yield per hectare, reducing yield loss or shortening the waiting period to start harvesting a normal yield might motivate their decisions to cultivate new varieties and maintain them in their fields.

3. The Choice Experiment and Data

We use choice experiment (CE) to evaluate farmers' preference for the various traits of coffee varieties. The attributes included in the CE are: i) yield, ii) weather tolerance, iii) disease resistance, iii) maturity period, and iv) cost of the seedlings.

CEs are based on a combination of Lancaster's characteristics theory of value (Lancaster, 1966), and McFadden's (McFadden, 1973) random utility theory. Lancastrian characterstics

theory states that the total utility of a good is derived from the characteristics or attributes of the good (Lancaster, 1966); while random utility theory states that individuals will choose any alternative that provide them with maximum expected utility. CEs enable us to study goods and attributes for which no market (yet) exists (Hanley et al 2001). In CEs, individuals are asked to make repeated hypothetical choices among alternatives in choice sets where the pre-specified levels of the different attributes vary.

3.1. Definition of attributes and attribute levels

Using information from the pre-testing, discussions with focus groups, key informants, model farmers and extension workers in the study area as well as discussions with experts, we selected five coffee attributes to define new coffee variety alternatives. The coffee attributes included in the choice profiles are: i) yield, ii) weather tolerance, iii) disease resistance, iv) maturity period and v) cost of the seedling.

The procedures in the selection of attributes and definition of their levels are based on review of previous studies and examination of opinions expressed in carefully crafted focus group discussions that include experienced and model farmers, ordinary farmers and agricultural researchers (mainly coffee breeders) as well as extension workers in the area. The experts on crop breeding and agricultural researchers have hands-on experience and practical knowledge of which coffee attributes are important. Similarly, the discussants reported that they considered the attributes as important for their selection of a particular coffee variety. The additional payment to fund the breeding program to improve the coffee attributes is operated as an extra cost of seedling for that particular coffee plant, and it is included along with the attributes. Table 1 presents the description of the attributes and attribute levels.

Table 1: Attributes and attribute levels, including the "no change" levels of the opt-out option, used in the choice experiment

Attribute	Description	Attribute levels
Yield	Increased average productivity in terms or yield per hectare of a particular coffee variety	No change, 1/4th increase, 1/3rd increase
Weather tolerance	Whether the coffee variety is tolerant to drought and frost and gives stable yield in the face of such weather stress factors.	No change, Drought only tolerant, Drought and frost tolerant
Disease resistance	Whether the coffee variety gives stable yield despite the occurrences of coffee diseases or pest infections in scenarios of no drought and/or no cold weather.	No change, Moderate disease resistant, Strong disease resistant
Maturity period	The time (in years) the coffee variety needs before giving its first normal yield.	No change*, 3 years, 5 years
Extra Cost per seedling	The additional payment, in Ethiopian Birr (ETB), households are expected to pay per seedling	0, ETB 7, ETB 15, ETB 20, ETB 25

Notes: # ETB = Ethiopian birr; at the PPP conversion factor on 31 December 2016, 1 USD=8.68 ETB;

* "no change" in the opt-out option correspond to a maturity period of approximately 7 years for the traditional coffee varieties. No change to weather tolerance and diseases resistance traits are associated with a little drought and frost tolerance and a little disease resistance respectively.

Yield refers to the increase in average productivity of a coffee variety in quintal (1 quintal (Q) = 100 kg) per hectare. The improvement in yield has been emphasized by policy makers and development practitioners aiming at increasing farmers´ income and ensuring food security. The yield attribute has three levels: no change (the current yield per ha), and 1/4th (one fourth) and 1/3rd (one third) increase in productivity. The current yield per ha varies with difference in production systems and the coffee varieties. The average productivity in quintal per hectare (Q/ha) is 2-3 for forest coffee, 4-5 in semi-forest coffee, 7-8 for garden coffee and 9 for plantation coffee, and the national average is 6-7 Q/ha. The productivity for selected varieties and hybrid varieties is the range of 6-17 Q/ha and 15-24 Q/ha, respectively. Increased yield per hectare raises household income, and is expected to have a positive effect on farmers´ willingness-to-pay (WTP) for seedlings of a coffee variety.

The few common pests and coffee diseases include coffee berry disease (CBD), *Meloidogyne spp*. and coffee rust. The impact of coffee diseases vary greatly with environments. Orange leaf rust is serious in hot climate, but less active at higher altitudes. Coffee berry diseases

(CBD) affect the physiological order of the plant and make the plant vulnerable or receptive to diseases, and slow down the ripening of the fruit (Muller*, et al.*, 2009). They added that parasite fungi such as *Collectorichum* sp. causes dieback and *Cercospora* leaf blotch causes *Cercospora coffeicola (*known as *brown eyespot of coffee),* but improved agricultural programs might solve these problems. The threat of CBD remains prevalent in different coffee growing regions despite research efforts and policy interventions encouraging planting of resistant coffee varieties and fungicide spraying (Dubale & Teketay, 2000). Pest and disease resistant cultivars yield economic benefits because they reduce yield losses and pesticide costs of coffee growers (Hein & Gatzweiler, 2006).

Weather tolerant and disease resistant traits are associated with the performance of the coffee variety in terms of giving a stable yield. *Weather tolerance* refers to the capacity of the coffee variety to withstand drought and frost, and to give a stable yield year after year. This attribute has three levels: no change (meaning little drought or frost tolerant), drought tolerant, and drought and frost tolerant. *Disease resistance* refers to the resilience and resistance of the coffee variety to coffee diseases and pest infections when there is neither drought nor frost, and give a stable yield year after year. The disease resistant attribute has three levels: no change (meaning little disease resistant), resistance only to common diseases, and high resistance to common and uncommon diseases. Increased weather tolerance and disease resistance are expected to increase farmers´ WTP for coffee traits.

The last coffee attribute farmers consider relevant to them and their community is the maturity period. *Maturity period* refers to the duration of time (in years) the coffee plant need to be fully developed and start giving a normal yield. The maturity period attribute has two levels: five years and three years. An increase in the maturity period of the coffee is expected to have a negative effect on household wellbeing and their preferences for the coffee variety. The *Cost* attribute is defined as *extra* costs per seedling. The average cost of a coffee seedling in the area at the time of the survey was approximately ETB 5-7.

3.2. Experimental design, Survey and Sample

This study employs orthogonal main effect experimental design (OMED) to combine attribute levels and create choice sets. In creating the choice sets, R code is used to execute

the experimental design and randomly assign the choice sets into two blocks. The experimental design creates 16 choice sets, and the two blocks include eight choice sets each. The choice sets consist of two new alternatives and an opt-out option. Similar to Meyerhoff and Liebe (2009), this study imposed restrictions to avoid unrealistic choice tasks by making the new alternatives have at least one higher attribute level than the opt-out alternative. This avoids new alternatives having inferior values to the opt-out option, but they can have higher extra costs. The presence of new alternatives with higher/lower non-monetary attribute levels but less/equal cost (dominant/dominated alternatives) than other alternatives is important in order to examine whether respondents give enough attention to and understand the choice task.

The choice tasks put respondents in a hypothetical setting, offering them choice sets comprising two new alternative coffee varieties at extra costs along with an opt-out option, asking them to choose their most preferred option. The alternatives in the choice sets differ in one or more of the attribute levels. The choice sets present generic alternatives in terms of "Alternative A", "Alternative B", and an opt-out option ("Neither Alternative A nor B") representing the traditional coffee variety. The respondents are randomly assigned to the two blocks, and each respondent faces eight choice sets asking them to choose whether to cultivate one of the two new coffee varieties on their farm or keep the traditional one. The two new coffee varieties come at an extra cost of the seedling in order to cover the costs of developing a new variety. The opt-out option has no extra cost of the seedlings as the farmers will then have the traditional coffee variety.

A pre-test survey was conducted in April 2016, and 36 households from the study area who were engaged in farming activities (but not coffee specifically) at the time of the survey were randomly selected. As each respondent faced eight choice sets in the in-person interview, this yields 288 unique observations. The results and experience from the pre-test were used to re-define and clarify the attributes for the survey instrument used in the final survey. In the pre-testing, the researcher assessed whether the respondents considered the program, the development of traits under examination and the general coffee breeding program, relevant to community. Similarly, each respondent is subjected to only eight choice sets in the final survey, and this might help to reach a balance between fatigue and learning

(Caussade, *et al.*, 2005). The fact that choice sets include generic alternatives such as "Alternative A" and "Alternative B" along with the "Neither" option might make subjects focus on the attributes/traits rather than the names we could have put on the alternatives/ coffee varieties. The "Neither" or opt-out option does not contain information about the levels of the attributes, but just says "I prefer none of the new varieties". Figure 1 shows a choice set/choice card as it was presented to the respondents.

Which of the following coffee varieties do you prefer? Alternative A and Alternative B would entail a cost to your household, while no payment would be required for the "Neither" option

	Alternative A	Alternative B	
Yield	1/4th increase	1/3rd increase	Neither
Weather tolerance	Drought and frost	Drought	Alternative A nor
Disease resistance	Disease resistant	Disease resistant	Alternative B:
Maturity duration	3 years	5 years	
Cost per seedling	ETB 5	ETB 20	I prefer none of the new varieties

I would prefer: Alternative A ____ Alternative B ____ Neither ____

Note: ETB = Ethiopian birr; 1 USD=8.68 ETB in terms of Purchase Power Parity (PPP) corrected exchange rate on December 31st 2016.

Figure 1. Example of a choice card as it appeared in the questionnaire in the final survey.

After translating the questionnaire into the local language, Tigrigna, the final survey was carried out in May 2016 by seven experienced enumerators who were trained for three days in survey techniques. The enumerators used a scripted introduction so that all respondents received the same amount of introductory information. The survey was conducted as face-to-face interviews of households from Raya Azebo and Raya Alamata districts in the Southern Zone of the regional state of Tigray, north Ethiopia. The study area is about 600 kilometers north of the Ethiopian capital Addis Ababa, and at 180 kilometers south of Mekelle, which is the capital of the Regional State of Tigray. The Central Statistics Agency (2007) of Ethiopia states that the regional state of Tigray has more than four million inhabitants, and agriculture is the major source of livelihood for the people.

In the final survey 358 smallholder farm households were interviewed with a face-to-face (f2f) interview. The sample households were selected with proportional and systematic random sampling from household name lists in the sub-district administrative offices, where the districts and villages with larger population get proportionally higher quotas. Household heads were selected for the f2f interview. During the interview, enumerators start by explaining the proposed breeding program and possible improvements in the coffee traits/attributes to the respondents in order to help them prepare for the choice experiment. After addressing questions from the respondents, if any, the enumerators proceed to the choice experiment. Then information about the household and socioeconomic characteristics of respondents are collected. The final data includes on 358 farmers (4 % of them are female) with a total of 2844 observed choices. Table 2 summarizes the socioeconomic characteristics of the sample.

Table 2: socioeconomic variables used to explaining variations of household's coffee trait preferences.

Variable	Mean	Definition
Age	43.2	Age of the household head; in years
Family size	5.7	The number of family members in the household
Gender	0.04	Gender of the household (1 = Female, and 0 = Male)
Education	1.8	Education level of the household head; in years
Market	60	The distance to the main market from the residence; walking time in minutes
Farm size	2.9	The area of the farm land the household owned in Timad (1 hectare= 4 Timad)
Irrigable land	0.44	Whether the household owns irrigable land; (0=No; 1=Yes)
Experience	0.28	Whether the household has experience in coffee farming; (0=No; 1=Yes)

3.3. Model specification and Estimation

The conditional logit model is commonly used to analyze consumer choice behavior based on random utility theory (RUT) (McFadden, 1974). Conditional logit assumes the idiosyncratic errors to be independently and identically distributed (iid) extreme values and

the tastes for observed attributes to be homogeneous. Evidence shows that individuals exhibit significant heterogeneity in preferences for goods and services (see Alberini & Ščasný, 2013; Allenby & Rossi, 1999; Birol*, et al.*, 2006). Interestingly, the mixed logit (MIXL) model relaxes the independence of irrelevant alternative (IIA) assumption of the more restrictive closed-form discrete choice models and allows for heterogeneity of preference for observed attributes (Hensher & Greene, 2003; McFadden & Train, 2000). In this model, utility U is assumed to be latent, but observed only with the choice Y of alternative j (0, 1, 2) by individual i (i=1, … 358) in choice situation/set t (t=1,2, … 8). A utility function given a choice set t with j alternatives for individual i can be written as;

$$U_{ijt} = \beta_i X_{ijt} + \varepsilon_{ijt}$$

Where X_{ijt} is a vector of observed explanatory variables including coffee attributes and sociodemographic characteristics. β_i is a vector of conformable parameters (unknown utility weights) the individual assigns to these variables; and ε_{ijt} is a random term that does not depend on underlying parameters or observed data, with zero mean and IID over alternatives. The utility weight (β_i) for a given attribute is given as;

$$\beta_i = \beta + \delta'_i v_{ij}$$

Where β is a vector of mean attribute utility weights in the population, δ is a diagonal matrix which contains the standard deviation (σ) of the distribution of the individual taste parameters (β_i) around the mean taste parameter (β), and v_{ij} is the individual specific heterogeneity with mean equal to 0 and standard deviation of 1. The MIXL model permits random parameters to vary over individuals, and not observation, in order to measure interpersonal heterogeneity. In this case, each respondent completed eight choice tasks; each consisting of two designed alternatives; Alternative A and Alternative B, and the "Opt-out" option. The vector X_{ijt}, can include 0/1 terms to allow for alternative specific constant (ASC), and it accounts for the systematic differences in choice patterns between the alternatives. The ASC is coded as 1 for "Alternative A" and "Alternative B" and 0 for the opt-out option. Behaviorally speaking, the ASC parameter reflects the average effect of various components such as endowment effect, status quo bias, omission bias, and the impacts of

complexity such as fatigue effects and other unobserved attributes (Boxall*, et al.*, 2009; Meyerhoff & Liebe, 2009) etc. The inclusion of an opt-out option can also reflect actual behavioral phenomena by avoiding forced demand, and hence improves the reliability of the welfare measures (Boxall*, et al.*, 2009; Veldwijk*, et al.*, 2014).

We set the parameters on yield, weather tolerance, disease resistance and maturity period attributes as random and with normal distribution, and the parameter on the cost attribute is set as fixed. A positive sign for significant coefficients of the attributes in the econometric estimation indicates a positive effect of the increase in the respective attribute on household preferences, whereas a negative sign indicates a negative effect of the attribute on household preferences. Statistically significant coefficients on the attributes also enables the calculation of WTP for a change in the attribute. In a utility function linear in its parameters, the marginal WTP equals the negative ratio of the respective coefficient of non-monetary attribute and the coefficient of the monetary attribute (Hensher & Greene, 2011). The WTP estimates presented in Table 4 refer to a marginal, one level change in the attributes. The attributes levels included in this model are presented in Table 1, and the sociodemographic variables are defined in Table 2.

The coefficients in MIXL models are estimated with a simulated maximum likelihood estimation technique. This study executed the gmnl-package in R to estimate the coefficients on alternative attributes and sociodemographic variables. Akike information criteria (AIC), Bayesian information criteria (BIC) and likelihood ratio tests in table 3 show that the MIXL model has superior goodness of fit compared to other models. The inclusion of the socioeconomic variables into MIXL model also increases the goodness of fitness of the model. Since the sociodemographic variables do not vary across choices/observations, their interaction with ASC are included to test whether they explain the observed taste variations across farmers or are random parameters across individuals.

4. Results and Discussions

Standard multinomial logit (MNL) models were estimated first, before proceeding to MIXL models. Other models such as simulated-multinomial logit model and generalized

multinomial logit model were also estimated; see appendix A-1. The results from the MIXL models show superior fit to the data in this study. In the MIXL estimation, we set the coefficients on the attributes yield, weather tolerance, disease resistant and maturity duration to be random parameters with normal distribution, while the coefficient on the cost of seedlings to be fixed in order to use it to compute WTP estimates. The maturity duration and cost of seedlings attributes are continuous variables, while the yield, weather tolerance and disease resistance attributes are categorical.

4.1. The Mixed logit model results

The coefficient on ASC is significant and positive, implying that farmers prefer the new alternative varieties at some additional cost to the existing varieties that come at no additional cost. Less than two percent of the respondents chose the opt-out option, but none of these respondents protested the proposed coffee variety development program and the changes in traits/attributes. ASC captures the average effect of all relevant factors that are not included in the model. Thus, farmers´ choice of new improved varieties over the traditional ones seem to be motivated not only by coping with frequent weather changes and occurrence of coffee diseases, but also by the desire for high yield and early maturing traits. Table 3 presents the results from the multinomial logit (MNL) and random parameter logit (RPL) models with and without sociodemographic characteristics.

Results from the MIXL model show that the estimated coefficients on yield, weather tolerance, disease resistance and maturity duration are all statistically significant. This implies that any developments in the specified coffee traits have significant influence on explaining farmers' preferences for coffee varieties. The parameter on the yield attribute is interpreted in relation to an increase in productivity per hectare or an increase in household farm income resulting from cultivating a particular coffee variety. The weather tolerance trait enhances resilience against drought and frosts, while the disease resistance trait increases resilience against coffee diseases and pest infections occurring under no drought and no frost weather conditions. Thus, the coefficients on disease resistant and weather tolerant traits can be interpreted as farmers´ preferences for yield stability or resilience to risk of yield loss, and hence indicate risk preferences of farmers. The parameter for the

maturity period attribute reflects the time preference of farmers. The signs of the coefficients for all attributes/traits are consistent with the standard economic theory as farmers prefer increased weather tolerance, higher disease resistance, and higher yield per hectare, but reduced duration of the maturity period and lower extra cost per seedling.

Table 3: Results of the MNL model and MIXL models without (MIXL1) and with (MIXL2) sociodemographic determinants of preference heterogeneity.

	MNL model	MIXL1 model	MIXL2 model
ASC	4.621***	8.750***	6.825***
	(0.220)	(0.572)	(0.600)
Yield high	0.754***	1.078***	0.838***
	(0.065)	(0.117)	(0.231)
Weather tolerant	0.970***	1.292***	1.453***
	(0.067)	(0.135)	(0.284)
Disease resistant	0.929***	1.425***	2.713***
	(0.061)	(0.131)	(0.521)
Maturity duration	-0.452***	-0.548***	-0.665***
	(0.034)	(0.071)	(0.129)
Cost of seedling	-0.044***	-0.058***	-0.065***
	(0.005)	(0.006)	(0.009)
Yield high. Experience			0.028*
			(0.012)
Weather tolerant. Irrigation			-0.001*
			(0.001)
Disease resistant. Education			-0.018*
			(0.009)
Disease resistant. Age			-0.063
			(0.045)
Maturity duration. Education			0.051**
			(0.018)
Maturity duration. Market			-0.005
			(0.004)
Maturity duration. Experience			-0.001*
			(0.001)
N	2860	2860	1869
Log-likelihood	-1765.161	-1594.251	-1131.047
BIC	3578.073	3315.839	2435.356
AIC	3542.321	3220.502	2308.094

Notes: Standard error in parentheses. ***, ** and * denotes significant at the 1, 5 and 10 % level; respectively

The significant and positive coefficient for the yield attribute implies that farmers prefer high yield coffee varieties to low yield coffee varieties, holding all other things constant. This implies that the improvement in the productivity per hectare of a coffee variety increases

the wellbeing of farm households, and hence the likelihood of farmers' preference for a new alternative variety increases. Previous CEs studies of annual crops (Asrat*, et al.*, 2010; Kassie*, et al.*, 2017) also showed positive effects of yield improvement attribute on farmer's preference.

Weather tolerant and disease resistant attributes are associated with the ability of a particular coffee variety to withstand environmental stressors and to give stable yield. The estimated coefficients for these two attributes are consistently significant and positive. This could imply that farmers are willing to pay more for seedlings with these traits, and are thus willing to give up part of their income in order to ensure stable yield. A CE by Asrat*, et al.* (2010) assessing the trait preferences of Ethiopian farmers for sorghum and teff crop varieties showed that farmers willingly forego some income or yield to obtain a more stable and environmentally adaptable crop variety. The coefficient on the maturity period is significant and negative, indicating that farmers have weaker preferences for coffee varieties that take longer to start giving normal yield. In other words, farmers have strong preferences for early maturing coffee varieties. Similarly, experimental evidence on rice traits in west Africa by Dalton (2004) found that farmers are willing to pay for early maturing traits. Note, however, that both Asrat*, et al.* (2010) and Dalton (2004) looked at annual crops, while coffee is a perennial crop.

Policy makers often stress on the importance of high yield varieties to meet the growing demand for food, but adoption of high yielding variety technologies is low. In this study, the results show that farmers are willing to pay more for the improvement of traits associated with yield stability such as weather tolerant and diseases resistant traits than for an increase in yield per hectare or early maturity. The magnitude of the coefficients corresponds to the importance the farmers put on the traits. In a related study, Kassie*, et al.* (2017) examined the preference of farmers for drought tolerant maize in rural Zimbabwe, and found that farmers are willing to pay five times more for a variety with a drought tolerance trait than for a variety providing an additional ton of yield per hectare. This implies that farmers are willing to forgo an increase in yield per hectare to get a stable yield on the farm. The subsistence nature of agriculture and escalated poverty in the area might restrain them from

adopting a high yield cash crop variety technology with some risk, and keep them trapped with a low yield and low cost variety technology.

Table 3 also reports the coefficients on socioeconomic factors that can explain preference heterogeneity among the farmers. Heterogeneity around the mean of the taste parameters is consistently apparent with respect to yield, weather tolerance, diseases resistance, and maturity duration traits. Therefore, we included age, education, experience with coffee farming, access to irrigation and distance to market to assess the observed sources of variation and to identify factors responsible for the heterogeneity. Thus, these socioeconomic factors were regressed simultaneously in the process of model estimation, and the inclusion of these socioeconomic factors gives rise to improvements in the conventional model fit criteria of log likelihood, Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC). Due to the observed heterogeneity, we rely more on the direct estimation from the MIXL model. Education, access to irrigation, and experience of the household in coffee farming were found to be the factors that explain variation around the average level of taste preference for the traits. About 28% of the respondents reported to have some experience in coffee farming activities, which explains preference variations for high yield and early maturing traits.

Considering the high yield trait, farmers with experience in coffee farming exhibit stronger preferences for improvements of yield per hectare than farmers without experience. This supports the fact that farmers in the study area are replacing low yield coffee varieties with improved coffee varieties and shifting towards cultivation of other more lucrative crops such as Khat. Farmers with relatively high levels of literacy are found to have weaker preferences for disease resistant traits. This is consistent with the finding of Gächter*, et al.* (2007) that an increased level of education decreases loss aversion. Similarly, farmers with better access to irrigation have weaker preference for weather tolerant coffee traits than the farmers who have no access to irrigation. This is because farmers with no access to irrigation are more likely to be vulnerable to drought, and hence become more risk averse.

The coefficient on the maturity duration attribute is negative. This implies an increase in maturity duration of the coffee variety has a negative effect on individual utility changes

(disutility). Farmers' years of education reduce the negative effect of increasing maturity duration of late-maturing coffee varieties, whereas coffee farming experience increases the negative effect of increasing maturity duration. This could be an effect of farmers´ private discount rate increasing with age and decreasing with educational levels and literacy, as observed by (Kirby, *et al.*, 2002). These days, almost the entire coffee farming area in the study area has been turned into production of Khat and other cash crops. Thus, farmers with coffee farming experience tend to be older, and older farmers could have higher private discount rates and thus prefer early maturing traits.

4.2. Willingness to pay for Coffee Traits

In CE analysis, the coefficients in themselves have no direct economic interpretation, but the negative ratio of the coefficients of the attribute to the cost coefficient give the marginal WTP estimate for the changes in the attributes. The WTP measures result from common choice-specific parameter estimates that are conditioned on the observed choices made by an individual (Hensher & Greene, 2003). The WTP estimates give some insight into farmers' preferences and the effects of attribute changes on household welfare. Negative WTP estimates reflect disutility of the attribute. The WTP for a change in an attribute level is the price increase, which combined with the attribute increase, leaves the deterministic part of the respondent's utility for a profile unchanged (Fiebig, *et al.*, 2010). The marginal WTP estimates show that the implicit price of high disease resistance and weather tolerance (frost and drought tolerant) is higher than high yielding and early maturing traits. This is justified as erratic weather is the most common challenge for coffee production in the study area in particular, and in Ethiopia in general. Table 4 presents the WTP of the four coffee traits.

Table 4: Marginal WTP; in Ethiopian Birr (ETB) (1 USD=8.68 ETB in terms of Purchase Power Parity (PPP) corrected exchange rate on December 31st 2016).

Attributes	WTP Estimates from the MIXL1 model	WTP estimates from the MIXL2 model
ASC	150	105
Yield_high	18	13
Weather tolerant	22	22
Disease resistant	24	42
Maturity period	-9	-10

Table 4 shows that the WTP of farmers for disease resistant and weather tolerant traits is higher than for high yield and early maturing traits. This implies that farmers prefer stable yield varieties to high yield varieties or early maturing varieties, holding all other things constant. These results are supported by the prevailing low adoption of high yield varieties by farmers in Ethiopia (Wale & Yalew, 2007). The coefficient on maturity period is significant and negative, which implies early maturity trait is more preferred to late maturing trait. The negative sign implies that farmers are willing to give up part of their income or yield to shorten the waiting period for the full development of the coffee plant and to start harvesting normal yield. In other words, farmers have disutility from a delay in the time it takes for the coffee seedling to give normal yield. The significant and positive coefficient on ASC implies that other unobservable systematic factors also increase households' preference for new alternative coffee variety over traditional varieties.

Observing the mean WTP estimates (deferring the heterogeneity), the farmers are willing to pay more for frost and drought tolerance as well as disease resistance traits, which is a premium about three times the amount they are willing to pay for a 1/3rd increase in yield of 1 quintal/ha (1 quintal=100 kg). The higher value farmers attach to a weather and disease resistant coffee variety in this study might reflect the difficulties in making inter-annual adjustment in coffee farming practices. Similarly, farmers also value early maturing coffee varieties but these turns out to be less preferred when compared to weather tolerant, disease resistant and high yielding varieties. In a related study on farmers' preference for maize traits in Zimbabwe, Kassie*, et al.* (2017) show that the value farmers attach for drought tolerance is about 5 times higher than the implicit price they attach to changing a variety. Farmers are willing to give up part of the increase in yield in order to harvest stable yield year after year. They are also willing to pay significant amount, but about half the amount they are willing to pay to increase yield/hectare by 1/3rd, in order to start harvesting a normal yield one year earlier.

The standard deviations of the random parameter coefficients are statistically significant (see table A-2 in the appendix), which is evidence for the presence of heterogeneity among the farmers in terms of the mean WTP estimates for yield per hectare, weather adaptability, diseases resistance and early maturity traits. Column 3 (MIXL2_model) in Table 4 reports

the effect of sociodemographic factors explaining the observable preference heterogeneities for coffee traits among the farmers. The WTP of farmers for the traits varies corresponding to the heterogeneity determinants. Farmers with experience in coffee farming are willing to pay more for high yielding traits and early maturing traits than the farmers without experience in coffee farming. In contrast, farmers with more years of education are willing to pay less for diseases resistant traits and early maturing variety. As could be expected, at least for drought tolerance, farmers with access to irrigable farmland are willing to pay less for weather tolerant coffee traits.

5. Conclusion

Understanding farmers' preferences for coffee traits can help develop policies and breeding programs for new varieties that integrate traits in demand by the farmers, and thus increase farmers' adoption of new varieties. Using a choice experiment, this paper examines farmers' preferences for increased yield, weather tolerance in terms of adaptation to drought and frost, disease resistance and early maturing traits of Arabica coffee. The results show that farmers are willing to cultivate and pay more for weather tolerant and disease resistant coffee varieties than high yielding and early maturing ones. This indicates that farmers have stronger preferences for improvements in yield stability traits than for traits that maximize yields. Thus, crop-breeding programs aiming for larger uptake of new coffee varieties among farmers in order to increase coffee production should primarily develop weather tolerant and disease resistant varieties, and combine them with high yield and early maturing traits.

Although farmers show stronger preferences for stable yield than for high yield traits, the mixed logit model results show heterogeneity in farmers' preferences for the coffee traits. Farmers with coffee farming experience exhibited stronger preferences for high yielding and early maturing coffee traits than those that had no experience in coffee farming. In contrast, farmers with more years of education reveal weaker preference for early maturing traits and disease resistant traits. Further, farmers with access to irrigable farmland exhibit weaker preferences for weather tolerant traits. This implies that tailoring the improved coffee varieties to the preferences of these different categories of farmers would enhance farmers' adoption of the new varieties.

The trait preferences of smallholder farmers also have implication for *in-situ* versus *ex-situ* conservation of coffee genetic diversity in Ethiopia. Smallholder farmers with no experience in coffee farming will not cultivate and maintain coffee varieties in their fields if yields are unstable, as they show stronger preferences for the yield stability traits of weather tolerance and disease resistance. Thus, the uptake of varieties with high yield and early maturing traits will be low among farmers in regions without a history of coffee growing. *Ex-situ* conservation programs should therefore give priority to coffee varieties with these and other traits that are less preferred by farmers in order to preserve the full coffee genetic heritage of Ethiopia.

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Appendices

Table A-1: Results of a Multinomial logit (MNL) model, Simulated Multinomial logit (S-MNL) model, Mixed logit model with correlated alternatives (MIXL), Mixed logit model without correlation (MIXLU), and a generalized multinomial logit (G-MNL) model, standard error in parentheses.

	MNL	S-MNL	MIXL_U	MIXL	G-MNL
ASC	4.621***	25.530	8.512***	8.392***	9.636***
	(0.220)	(16.563)	(0.559)	(0.512)	(0.813)
Yield high	0.754***	1.907**	1.067***	1.041***	1.198***
	(0.065)	(0.701)	(0.108)	(0.113)	(0.143)
Weather tolerant	0.970***	2.309*	1.421***	1.252***	1.342***
	(0.067)	(0.965)	(0.125)	(0.122)	(0.145)
Disease resistant	0.929***	2.092**	1.366***	1.388***	1.631***
	(0.061)	(0.717)	(0.119)	(0.127)	(0.173)
Maturity duration	-0.452***	-1.406*	-0.734***	-0.493***	-0.593***
	(0.034)	(0.595)	(0.069)	(0.063)	(0.065)
Cost seedling	-0.044***	-0.112*	-0.064***	-0.056***	-0.065***
	(0.005)	(0.046)	(0.006)	(0.006)	(0.007)
Tau		1.410***			0.477***
		(0.323)			(0.091)
Gamma					-0.648
					(0.354)
N	2860	2860	2860	2860	2860
Log-likelihood	-1765.161	-1751.089	-1632.741	-1596.428	-1577.198
BIC	3578.073	3557.888	3345.067	3320.192	3297.651
AIC	3542.321	3516.178	3285.482	3224.855	3190.396

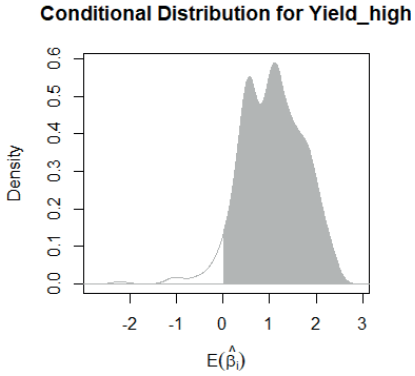
Notes: ***, ** and * denotes significant at the 1, 5 and 10 % level; respectively.

Table A-2: Standard deviations of the random parameters from mixed logit model results

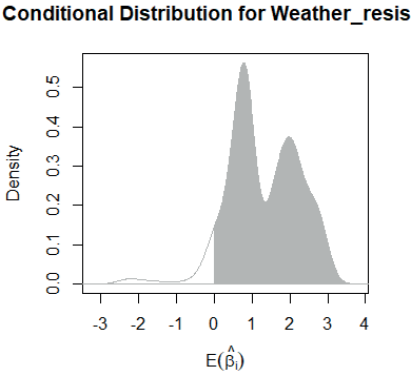
	Estimate	Std. Error	z-value	Pr(>|z|)
Yield high	1.0931	0.1985	5.51	3.7e-08 ***
Weather tolerant	1.3818	0.1906	7.25	4.2e-13 ***
Disease resistant	1.3674	0.2494	5.48	4.2e-08 ***
Maturity duration	0.6452	0.0964	6.69	2.2e-11 ***

Note: ***, ** and * denotes significant at the 1, 5 and 10 % level; respectively.

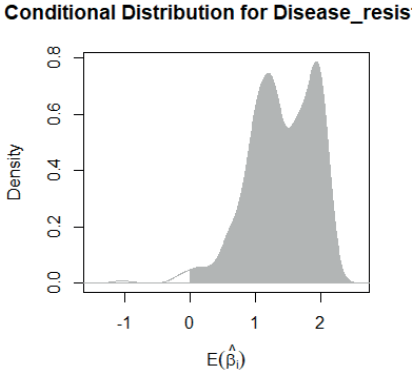
Figure A-1: the distribution of the individuals' conditional mean for the parameters of yield, weather tolerant, diseases resistant and maturity duration (the grey area displays the proportion of individual with positive conditional mean).



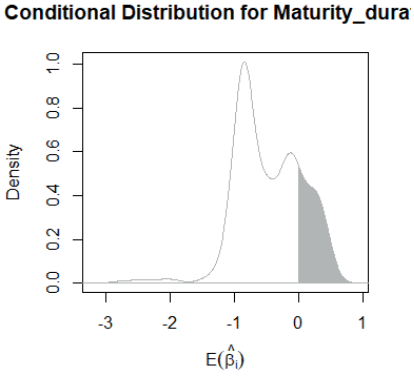
a) Kernel density for yield improvemnt



b) Kernel density for weather tolerant



c) Kernel density for Disease resisteaänt



d) Kernel density for Maturity duration

How Does Climate Change Skepticism affect Preferences for Forest Conservation in Developing Countries[5]?

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Abstract

Environmental skepticism is a pervasive social phenomenon, and can become an obstacle for implementing climate change adaptation and mitigating measures. However, as there is little evidence on the nature and causes of environmental skepticism, and how it influences preferences for forest conservation programs, this study aims to shed light on the effect of environmental skepticism in a developing country context. A contingent valuation survey of 358 Ethiopian households elicited their willingness-to-pay (WTP) for a forest conservation program, and measured their degree of environmental skepticism on 1-10 Likert scale. This study has two key findings. First, the respondents have significant and positive WTP for improved forest conservation. Second, environmental skepticism variables play a significant role in determining public support for forest conservation. Respondents who believe that the threat of climate change is exaggerated in public discussions, and/or do not believe in human induced climate change, are less likely to pay for the forest conservation. In contrast, respondents who believe in the forest conservation as a climate change mitigating measure, and/or those who believe in the importance of considering long-term consequences of adaptation actions, are more likely to pay. Higher deforestation awareness and education also increases the likelihood of paying for conservation programs. Significant WTP estimates indicate the presence of potential financial resource from the local households in developing countries to implement payment for environmental services contracts to boost forest protection.

Key Words: Environmental Skepticism; Forest Conservation; Willingness to pay; Contingent Valuation
JEL: Q5; Q210; Q230; Q510

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1. Introduction

Public skepticism surrounding climate change and global warming is an obstacle for implementing environmental sustainable measures in many countries (Akter, *et al.*, 2012). Environmental skepticism is a disbelief about the authenticity or severity of environmental degradation (Hobson & Niemeyer, 2013; Poortinga*, et al.*, 2011), and includes the belief that all the claims that the environmentalists and environmental scientists make are false and exaggerated (Dryzek*, et al.*, 2011). Environmental skepticism is a widespread social phenomena among the general public, and it stems from insufficient education and self-assessed environmental knowledge, religious and conservative values, lack of trust in general society and science, and other concerns competing with environmental concern (Zhou, 2015). Zhou (2015) argues further that measures towards low education and self-assessed environmental knowledge are more effective in reducing skepticism among the less religious individuals than among religious and right-leaning conservatives. Since a significant proportion of Ethiopian people are religious and illiterate, there is large social base for public environmental skepticism, which could limit public commitment to share the economic burden of mitigating domestic climate change impacts. However, to my knowledge, no study has examined the effects of environmental skepticism on preferences for domestic climate change adaptation measures to mitigate deforestation and biodiversity loss in developing countries.

This paper examines public environmental skepticism of households, and investigates the role of environmental skepticism variables in predicting the willingness-to-pay (WTP) for forest conservation. One of the four pillars to achieve the climate resilient green economy (CRGE) endeavor that Ethiopia currently has initiated is protecting and re-establishing forests for their economic and ecosystem services, including being carbon stocks. The government has registered 58 national forest priority areas (totaling 48000 km^2) to conserve the country's remaining forests. Forests help to avoid the adverse effects of climate change and in sheltering large numbers of species, including some that are not found in the wildlife conservation areas. This study targets the Hugumburda-Gratkahsu (hereafter H-Gk) forest priority area, which is the only Afromontane forest in the Tigray Region, Northern Ethiopia.

Despite being officially protected, the forest priority areas are generally characterized by weak management capacity and continuously degrading landscapes. The majority of these forest areas have shrunk due to population pressure: increasing demand for cropland, grazing, settlement, and deforestation (Birhane*, et al.*, 2019; Kidane*, et al.*, 2016). Rural poverty, growing populations, deforestation along with climate change persist threatening the forest. The implementation of adequate protection measures to overcome the pressures and threats encountered in the forests needs considerable public support. However, even milder form of environmental skepticism with a broad popular base can be a greater barrier to implement environmental policies.

Integrating proper adaptation measures into national development and mitigation policies requires a better understanding of adaptation behavior of households and factors determining choices of adaptation measures. Evidence shows that adaptation options of Ethiopian households are affected by information constraints. However, very little is known about the role of public environmental skepticism for the public support of sustainable adaptation measures. This study examines public environmental skepticism attitudes and their influence on the WTP for improved forest conservation.

Respondents in the face-to-face (f2F) survey of households in the Tigray Region in Northern Ethiopia were asked a series of seven questions relating to different dimensions of skepticism: (a) attribution skepticism, in terms of whether climate change is caused by "God", and not by human actions; (b) impact skepticism, questioning the seriousness of the climate change issue; and (c) mitigation skepticism, questioning how effective a proposed mitigation scheme will be in slowing down climate change. The skepticism questions are about individuals accepting or rejecting the scientific conclusions about the cause, consequence and remedy of climate change. The respondents were asked to state to what extent they agree with statements on the above climate change skepticism accounts using 1-10 Likert scale (1 "do not agree at all" and 10 is "completely agree"). Then, the skepticism variables along with socioeconomic variables were regressed on the contingent valuation discrete choice yes/no responses to the WTP to a stated amount for forest conservation.

This study has two main contributions to the literature on the economics of forest conservation programs. First, it explores which aspect of environmental skepticism influence decisions to support forest conservation measures. Second, the WTP estimates from this study give insight about the potential of the financial resource from local households for implementing payment for environmental services (PES) contracts to address biodiversity losses, deforestation and other ecological problems. The PES schemes offer promising prospect to address deforestation and rural poverty problems in developing countries (e.g. Asquith*, et al.*, 2008; Austin*, et al.*, 2014; Wunder, 2005; Zander & Garnett, 2011).

The rest of the paper is organized as follows: Section 2 describes the forest area under study and the survey methodology. Section 3 describes the results from contingent valuation, and section 4 concludes.

2. Method

2.1. The forest site, sampling and survey

This study considered two contiguous forests: Hugumburda and Grat-Kahsu (H-GK) forest situated in the Southern Zone of the regional state of Tigray, north Ethiopia. The H-GK forest covers the mountain range extending from above Alamata town in the south to Maichew town in the north. The forest covers an area of 20000 hectares, of which 1200 (6%) hectare is plantation forest. Broad-leaved plants, coniferous, junipers, olive, dodonea and grewia tree *inter alia* are the dominant species in the forest. While not well documented, the forest is habitat for a large number of highland-biome bird species as well as leopard, klipspringer, antelope (gazelle) and grey duiker. The H-GK forest is identified as one of the four international bird areas (IBAs) in the region as it is an important *habitat* for birds from the three biomes: Highland, Somali-Massai and Sudan-Guinea biomes. The Abyssinian Catbird, Rupell's Chat, Black headed Siskin among others are endemic to the area, while five other bird species are endemic to Ethiopia and Eritrea. Besides offering communal grazing area, the forest provides other provision ecosystem services (ES) like wild fruits, food, plants for medicinal use, fuel wood and building and craft materials to the households that live inside

and outside the forest. The forest also provides regulating services like soil erosion protection, and cultural ecosystem services in terms of spiritual, aesthetic services and other amenity values contributing to human wellbeing.

The Ethiopian government has currently registered the H-GK forest as national forest priority area following the drastic deterioration of natural forests in the country. The government has thus implemented some natural regeneration and afforestation measures to try to preserve the remaining fragmented forest of the H-GK. However, the growing population along with growing demand for farm and pasture land as well as climate change impacts remain a threat to the continued survival of the forest. There is no official map nor register of individually held farm and pasture land located within the forest, as the area is officially part of the state forests. The absence of enforced legal rights and proper conservation programs pose a further threat to conservation of the H-GK forest and its biodiversity and ecosystem services.

A pilot survey was conducted, and used to revise and refine the survey instrument. In the final survey, household heads of 358 smallholder farm households in Raya Azebo and Raya Alamata districts on down the slopes of the H-GK mountain forest were surveyed. The respondents were selected using systematic random sampling from household name lists in the sub-district administration centers. Well-trained interviewers guided the respondents through the face-to-face (f2f) survey. A f2f survey was the only possibility here as the illiteracy rate is high in the area.

2.2. Survey design

The survey instrument includes questions on WTP for conservation of the H-GK forest, environmental skepticism and socioeconomic characteristics. A double-bounded dichotomous choice (DBDC) CV design was employed to elicit their WTP. Respondents were first asked if they would be willing to pay anything at all for the conservation of the H-GK forests and its biodiversity. If they said "yes", the conservation program was offered to them at one of three different initial amounts/bids (ETB 125, ETB 250, and ETB 500; 1 USD= 8.68 Ethiopian Birr (ETB); Purchase Power Parity corrected exchange rate in the year of the survey; December 31st 2016). The payment was to be collected annually in terms of an

environmental tax for five consecutive years. Depending on whether they said they would vote "yes" or "no" to the forest conservation program at the initial bid, they were asked in a follow up question to pay a higher or lower amount, respectively. The initial amount was doubled if the respondent said "yes" to the first bid, and halved if the respondent said "no" to the first bid (see figure 1). This enables the estimation of mean WTP from their replies to both the initial and the follow-up bid in a double bounded dichotomous choice (DBDC) model, but also using just their replies to the initial bids in a single bound dichotomous choice (SBDC) model.

Figure 1: Design of the Double-Bounded Dichotomous Choice (DBDC) Contingent Valuation (CV) scenario. Respondents received one of three initial bids (ETB 125, 250, 500 and 125) and a follow-up with a lower or higher bid if they said "no" or "yes" , respectively, to the initial bid.

The survey also asked respondents to state the reasons for accepting or rejecting the proposed conservation programs. Everyone was willing to be asked, and no one protests the conservation program. Respondents were also asked to state their level of awareness of the wildlife species in the forest and the current deforestation problem, as well as a list of statements aiming at revealing their level of environmental skepticism. They were also asked whether they were benefiting from the forest (grazing and fire wood collection etc.), and which payment mode they would prefer the most to pay the stated bids in; cash, in-kind (crop) or labor time.

2.3. Contingent Valuation Scenario

In the CV scenario, respondents are told that sustaining the H-GK forest and its biodiversity would require new conservation measures. The CV scenario emphasizes biodiversity conservation as the main goal of the forest conservation program, and states that there is an obvious need for financial resources for conservation measures like clear demarcation of the forest borders, and patrols to curb timber harvesting and avoid further encroachment of the forest from farming and grazing. Respondents were also told that the biodiversity could still be found in other regions of the country although it may go extinct locally without adequate forest protection.

The purpose of the conservation program is preserving the H-GK forest and sustaining its biodiversity and avoiding the risk of species extinction locally. The CV scenario included the following reminder to the respondents (Box 1).

We want you to consider the following points while you make decisions about your willingness to pay.

i) The aim of the conservation program is only to preserve the H-GK forest, whereas other environmental concerns such as global warming and ozone depletion may still require more finance.

ii) Consider your income constraint, household expenses and others things you care for.

iii) Other forest sites in the country may still provide some similar benefits although not as important and accessible to you as in the H-GK forest.

iv) The conservation program will be implemented, and everyone will have to pay if the majority of people vote "yes" to paying the amount.

v) The program will guarantee to refund the exact amount of money you paid (or its equivalent if you paid in labor or in-kind) if it fails to implement the proposed conservation tasks.

Box 1: Reminder presented to the respondents as part of the Contingent Valuation scenario.

Most respondents prefer to pay under the environmental tax scheme separated from the land tax that the government collects annually, because the land tax has nothing to do with the local activities such as forest conservation and the respondents do not want the budgets to be mixed. In cases where there is mistrust in government, CV studies would typically yield an extremely high number of protest responses (e.g., Markowska & Żylicz, 1999). All respondents in our survey accepted the conservation program, and there were no protesters. This could be due to the fact that respondents are told that they can choose local delegates who can check upon and supervise whether the collected money is spent exclusively on the project, and that heir payment is conditional on the successful implementation of conservation project.

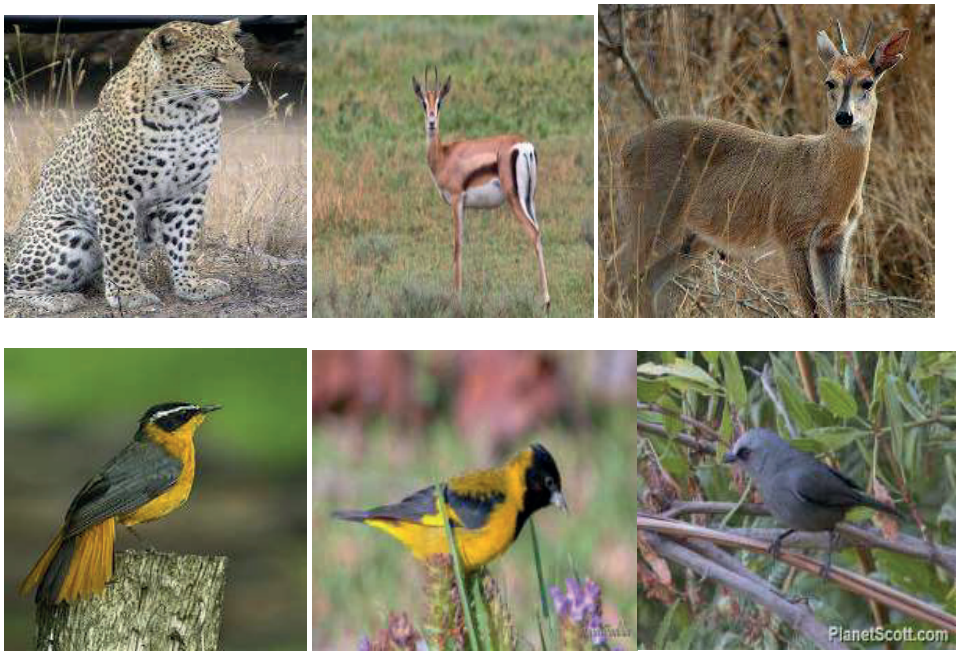

Figure 2: Photos of mammals and birds found in the Hugumburda and Grat-Kahsu (H-GK) forest shown to the survey respondents.

The CV scenario focused on biodiversity conservation, but the respondents had difficulties in understanding the concept of biodiversity during the pilot survey. Hanley, *et al.* (1995) and Christie, *et al.* (2006) also found that most respondents had low awareness and poor

understanding of biodiversity, and that this is a challenge to stated preference surveys. In an attempt to mitigate this problem in our final survey, we showed respondents photos (see figure 2) of birds and animals such as leopard, klipspringer and grey duckier, and also mentioned some of the common plants such as coniferous, junipers, olive, dodonea and grewia etc. in the forest. This seem to have improved respondents´ understanding of biodiversity, as we then give respondents the same minimum amount of information about the species preserved which would otherwise go extinct locally if conservation measures were not in place.

2.4. Self-reported level of environmental skepticism

In order to map respondents´ level of environmental skepticism, they were presented with different statements about the causes and consequences of climate change and proposed solutions to mitigate climate change impacts. For each statement, they were asked to indicate to what extent they agreed with the statements; using 1-10 Likert scale, where 1 is "do not agree at all" and 10 "completely agree"). The statements were:

- God is the cause of climate change, and people do not need to do anything to prevent climate change.
- The climate change discussions and news by media and in public discussions are exaggerated.
- The conservation activities carried out by the government are sufficient to protect the environment.
- Forest conservation programs contribute towards mitigating climate change impacts.
- The activities of humankind do not accelerate climate change.
- Humankind can overcome any pressure from environmental and climate change problems with the advent of technology.
- One should consider the long-term consequences (in 50 years' time) of measures rather than focusing only on present gains.

Public environmental skepticism attitudes can be obstacles for endeavors to prevent the ongoing deforestation and climate change problems. Attitudes reflect one's predisposition

to evaluate some symbols or aspect of the world in a favorable or unfavorable manner, and this might influence the decision on whether to support forest conservation programs or not. Perloff (2010) argues that the predisposed state of mind regarding the value of some object or the surrounding world in turn influences individuals' thoughts and actions. In answering the above questions, the respondents reveal their belief or disbelief and trust or mistrust of particular environmental realities or scientific accounts related to climate change issues. Since environmental skepticism is not the only factor that influences whether to support conservation decisions, the study also collected information on the socioeconomic characteristics and environmental awareness of respondents. Table 1 presents the skepticism and socioeconomic variables included in this survey.

3. Results

3.1. Descriptive statistics

The study explores public environmental skepticism, socioeconomic factors and environmental awareness variables that can influence the probability and willingness to pay for improving forest conservation. The skepticism variables include attitudes on accounts of climate change causes, media's discussion of climate change matters, the attitudes towards the adequacy of conservation measures undertaken by the government, contribution of forest conservation for mitigating climate change impacts and considering the long-term consequences of environmental measures. Table 1 presents the summary (mean and standard deviation) and description of the explanatory variables.

Table 1: Definition and summary statistics of explanatory variables in the Contingent Valuation (CV) survey (Mean and standard deviation of environmental skepticism, socioeconomic and other variables).

Variable	a. **Environmental skepticism variables** (To what extent do you agree on a n scale from 1 to 10, where 1 is "do not agree at all" and 10 "completely agree")	Mean	Std. dev.
God_causes	God is the cause of climate change, and people need not to take any measure to prevent climate change impacts.	4.9	3.4
Govt_suffcon	The conservation activities carried out by the government are sufficient to protect the environment.	8.7	1.7

Exgg_discsn	Climate change discussions and news by media and in public are exaggerated.	4.3	1.3
Forest_mitgte	Forest conservation programs contribute towards mitigating climate change impacts.	8.1	1.9
Hum_activity	The activities of humankind do not accelerate climate change	6.2	1.8
Technology_natr	Humankind can overcome any pressure from environmental and climate change problems with the advent of technology.	7.8	2.6
Longterm_consq	One should consider the long-term consequences (in 50 years' time) of measures rather than focusing only on present gains.	9.1	1.5

b. Demographic characteristics

Age	Age of the household head in years	42.5	13.6
Household size	The number of individual members in the household	5.7	0.5
Education	Education level of the household head in years	1.8	2.9

c. Income and wealth indicators

Farm size	The area of farmland owned by household in Timad (1 hectare= 4 Timad)	2.9	1.9
Livestock	The number of livestock owned by household in Tropical Livestock Units	2.7	2.1
Expenditure	The total annual household expenditure of households in Ethiopian Birr (ETB); used as a proxy for household income	20,890	12,334

d. Other variables

Wildlife_aware	Household 's level of awareness about the wildlife species in the H-GK forest; dummy variable where 1= Good or High and 0 = Low	0.65	0.48
Defor_aware	Household's level of awareness about the deforestation and threats to the H-GK forest; dummy variable where 1= Good/ High and 0 = Low	0.66	0.48
Forest_benft	Household's level of benefit from the H-GK forest: dummy variable where 1 = Good or high benefit and 0= No benefit at all	0.65	0.45
Pay_mode	The payment mode the households prefer (if they could choose; but all respondents were asked to vote "yes" or "No" to pay a bid in cash):		
	• in Cash	0.67	0.55
	• in Labor	0.27	0.45
	• In-kind	0.06	0.24

Note: At the PPP conversion factor on 31 December 2016, 1 USD=8.68 ETB.

Table 1, in the first section, shows that the respondents believe to some degree that "God is the cause of climate change", and that "Climate change discussions and news by media and in public are exaggerated." High values for these statements implies a high level of environmental skepticism, reduces pro-environmental behavior and the probability of paying for forest conservation. Table 1 also shows that respondents to a large degree believe that humankind can overcome climate change and environmental problems by technological developments, and that the conservation the government is carrying out today suffices. Respondents show a high degree of belief in the contribution of forest conservation programs to mitigate climate change impacts. This is likely to increase their support for forest conservation programs. The current community conservation practices in the study area are not sufficient to sustain the forest and its wildlife, as they mostly focus on fixing seasonal problems and overlooks long-term concerns.

Table 1 also reports the mean and standard deviations of socioeconomic characteristics of the respondents. The respondents are farmers engaged in production of cereal crops such as Maize, Teff and Sorghum, and commercial crops such as chat (Khat), coffee etc. Most of the farmers in the study area have a low level of literacy, which is illustrated by the household head's low average number of 1.8 years of formal education. Close to 2/3 of the respondents have good or high awareness of the deforestation problem and wildlife species in the forest, and nearly 2/3 get benefits (e.g. firewood and grazing) from the H-GK forest. In terms of respondents´ willingness-to-pay for forest conservation, 2/3 of the households prefer to pay in cash rather than in-kind or in terms of labor.

Table 2 reports the results from the DBDC CV questions. We divided the sample into three subsamples, receiving three different initial (first) bids: ETB 125, ETB 250 and ETB 500. We then doubled the second bid if respondents responded "Yes" to the first bid, and halved if they responded "No" to the first bid. Table 2 shows that about 56 percent responded "Yes" to both the first and second bid (i.e., the "Yes/Yes" column in table 2) when the first bid amount is ETB 125 (followed by ETB 250); about 51 percent responded "Yes/Yes" at ETB 250 (followed by ETB 500), and only 29 percent responded "Yes/Yes" when at ETB 500 (followed by ETB 1000).

Table 2: Double Bounded Discrete Choice (DBDC) Contingent Valuation (CV) responses (see figure 1 for the bid structure). Distribution of respondents (percentage in parenthesis) on "Yes" and "No" to first and second bid (e.g., "Yes/Yes" means "Yes" to both the first and second (upper) bid") for the 3 different first bids; 125, 250 and 500 ETB (Ethiopian Birr). The percentage of respondents saying "Yes" to these initial bids, i.e., a Single Bound Dichotomous Choice (SBDC) format, are the sum of Yes/Yes and Yes/No in the DBDC below; i.e., 85.6%, 78.5% and 59.0 % for ETB 125, 250 and 500; respectively.

1st bid	2nd bid (upper)	2nd bid (lower)	Yes/Yes	Yes/No	No/Yes	No/No	Total respondents
ETB 125	ETB 250	ETB 62.5	70 (56%)	37 (29.6%)	9 (7.2%)	9 (7.2%)	125 (100%)
ETB 250	ETB 500	ETB 125	59 (50.9%)	32 (27.6%)	10 (8.6%)	15 (12.9%)	116 (100%)
ETB 500	ETB 1000	ETB 250	34 (29.1%)	35 (29.9%)	19 (16.2%)	29 (24.8%)	117 (100%)

Note: The Purchase Power Parity (PPP)- corrected exchange rate on 31 December 2016, 1 USD=8.68 ETB.

Thus, as expected from economic theory, the percentage of respondents saying "yes" to the bid decrease with increasing bid size. Thus, the percentage of respondents saying "Yes" to the initial bid, i.e. a Single Bound Dichotomous Choice (SBDC) format, are the sum of Yes/Yes and Yes/No in the DBDC reported in table 2; i.e., 85.6%, 78.5% and 59.0 % for ETB 125, 250 and 500; respectively. Also, in the DBDC, the proportion of individuals saying "Yes" to both bids (i.e., the "Yes/Yes" column in table 2) decreases as the first bid amount increases.

3.2. Econometric analysis

Probit models are used to test the validity of the single-bounded discrete choice (SBDC) responses, in terms of which factors determine respondents' probability to vote "Yes" to support the forest conservation program at the initial bid. The explanatory variables include the initial bid amount, environmental skepticism, and awareness of deforestation and

wildlife in the forest, preferred payment mode and socioeconomic characteristics of respondents.

Model 1 in Table 3 use a probit model to regress household's acceptance of the initial bid on the bid amount only, and as expected from economic theory bid size has a significant negative effect on accepting the bid. Thus, households´ probability of accepting the bid decrease with increasing initial bid amounts. Models 2 and 3 add other explanatory variables in this probit model of the initial bids (i.e. SBDC models), whereas in Model 4 we use the "yes/no" responses to the all bids in DBDC to specify payment intervals in an interval regression model.

Table 3: Probit models (Models 1-3) of Single Bound Dichotomous Choice (SBDC) Contingent Valuation (CV) responses, and variables (see table 2 for definitions) determining the probability to say "yes" to pay for forest conservation. Model 4 is an interval regression model from the Double Bound Dichotomous Choice (DBDC) responses.

Variables	Model 1	Model 2	Model 3	Model 4
Bid	-0.617***	-0.609***	-0.710***	
	(0.13)	(0.14)	(0.15)	
God_causes		-0.049**	-0.046*	-2.215
		(0.02)	(0.03)	(9.37)
Exagg_discsn		-0.146**	-0.180**	-45.737**
		(0.07)	(0.07)	(22.78)
Govt_suffcon		0.023	0.041	18.716
		(0.04)	(0.05)	(15.89)
Forest_mitgte		0.052**	0.054**	7.446
		(0.02)	(0.03)	(8.94)
Hum_activity		-0.026	-0.065	-4.982
		(0.05)	(0.05)	(16.42)
Technoly_natr		-0.004	-0.004	1.368
		(0.03)	(0.03)	(11.19)
Longterm_consq		0.139**	0.136**	28.282
		(0.06)	(0.06)	(19.42)
Defor_aware			0.527**	173.407**
			(0.20)	(66.06)
Wildlife_aware			0.050	-24.665
			(0.16)	(55.43)
Forest_benefit			-0.371*	-38.766
			(0.19)	(61.87)
pay mode=labor			-0.461*	-238.594***
			(0.18)	(62.90)
pay mode=in-kind			-0.913**	-237.617* *
			(0.33)	(117.72)
Education			0.066**	16.484 *
			(0.03)	(9.91)
livestock			-0.004	-12.343
			(0.04)	(13.36)
Expenditure			0.161	52.592
			(0.17)	(56.27)
Farm size			0.050	17.309
			(0.05)	(16.19)
Household size			0.264	36.817
			(0.19)	(63.32)
constant	4.104***	4.100***	2.447	-304.872
	(0.74)	(1.10)	(1.81)	(566.96)
Sigma[6] constant				-429.675***
				(28.28)
N	357	353	350	351
Pseudo R-square	0.6	0.10	0.18	-
LR	-189.2	-179.26	-159.5	-435.0
AIC	387.2	380.6	366.4	915.3
BIC	394.9	415.5	439.8	988.7

*Notes: Significance levels. * p<0.1, ** p<0.05, *** p<0.01*

[6] [6] Sigma refers the standard deviation of the estimated mean WTP.

The probit Model 2 in Table 3 includes the environmental attitude and skepticism variables along with the bid. Most CV studies give emphasis to socioeconomic variables to explain households' decision to accept or reject DC bids. Results show that 4 out of 7of public environmental attitude and skepticism variables have significant effects on the probability of accepting the initial bid. Respondents with a high level of agreements with the statements "Forest conservation programs contribute towards mitigating climate change impacts" (*Forest_mitgte*) and "One should consider the long-term consequences (in 50 years' time) of measures rather than focusing only on present gains" (*Longterm_consq)*", as expected, significantly increase the probability of respondents accepting to pay the stated amount for forest conservation. This implies that households with strong pro-environmental attitudes are more likely to pay for improving forest conservation, and hence have higher mean WTP. Respondents stating a high level of agreement with the statements "God is the cause of climate change, and people need not to take any measure to prevent climate change impacts" (*God Causes*) and Climate change discussions and news by media and in public are exaggerated" (*Exagg_discsn*) on the other hand have a significant lower probability of accepting to pay the bid amount. Individuals who believe God to be the cause of climate change might be more religious individuals and/or those with poor knowledge of climate change. Their high levels of environmental skepticism reduce their probability of accepting the bids, and thus reduce the mean WTP. These results add to the evidence that public environmental skepticism reduces the likelihood of public support for forest conservation.

In model 3 we expand the probit model with socioeconomic and other variables, but the same 4 environmental skepticism variables are still significant with the same expected signs. Awareness of deforestation has significant and positive effect, implying that deforestation awareness increases the probability of paying the proposed bid, and hence WTP for forest conservation. Awareness of the wildlife in the forest does, however, not have a significant effect on the probability of paying for forest conservation. This indicates that it is the awareness of deforestation rather than the threat to biodiversity in the forest that motivates households´ WTP for forest conservation. While the level of education has a significant and positive impact on the probability of paying, household expenditures (which is often used as a proxy for income) is not significant. This could be because the expenditure level did not

vary much across the respondents, and/or that expenditures in this case is not a good proxy for household income (which is could be the case in communities as these with a sizeable barter economy).

Households who presently benefit more from firewood collection and grazing in the forest reveal significantly lower probability of paying for forest conservation (see Appendix A-2) perhaps because they think that the forest conservation program could terminate their present uses from the forest. Model 3 also shows that individuals' preferred payment mode matters to their decision to pay for forest conservation. Our survey specified the payment in cash, because it is the standardized measurement and easier to understand for the respondents, and most people in the pilot survey preferred the cash payment. Results show that respondents who prefer to pay in labor time or in-kind (i.e., crops) are less likely to pay for conservation than those who prefer to pay in cash, and hence have lower WTP. Similarly, Wunder (2005) found that payments modes matter in payment for environmental services (PES) schemes. Asquith*, et al.* (2008), however, stated that sellers of environmental services preferred in-kind to cash payments. The ES sellers are receivers of cash, and Asquith*, et al.* (2008) explain this finding by referring to Heyman and Ariely (2004) that state that low-value in-kind payments can be more effective than low-value cash payments in stimulating efforts, or that recipients might view in-kind transfers as more compatible with reciprocal exchange and traditional local systems of social markets.

Model 4 in table 3 utilize the DBDC data in an interval regression model. Also here environmental skepticism reduce the WTP, but only a high level of agreement with the statement "Climate change discussions and news by media and in public are exaggerated" (*Exagg_discsn*) have a significant negative effect, while "God is the cause of climate change, and people need not to take any measure to prevent climate change impacts" (*God Causes*) did not significantly affect WTP. Like in Model 3 we see that education (but not expenditures) and awareness of deforestation (but not wildlife) have significant, positive effect on WTP. Those in favor of paying in-kind or in labor, also still have a significantly lower WTP than those that prefer to pay in cash.

3.2. Willingness to Pay Estimation

We use the probit regressions and interval data regressions to estimate the WTP values from SBDC and DBDC CV responses, respectively. The WTP estimates are presented in Table 4, and are estimated at the mean values of the explanatory variables used in the regression models 3 and 4 in Table 3.

Table 4 reports the mean WTP estimates using both the SBDC and DBDC model. In the DBDC model, the follow-up questions after the first question improves the statistical efficiency and precision of the WTP estimates (Hanemann*, et al.*, 1991). Despite its efficiency gains, Hanemann*, et al.* (1991) pointed out that DBDC model requires a relatively large sample in order to make accurate estimation of WTP. Mean WTP in the SBDC model is estimated dividing the constant of the probit model by the bid coefficient, whereas mean WTP value from DBDC model is estimated using the interval regression model in Stata. In both cases, we include all the variables in Models 3 and 4 of Table 3, respectively, to predict mean WTP at the mean values of the explanatory variables. The results show mean WTP of households for forest conservation to be significant and positive. The estimates from the SBDC and DBDC models are not significantly different. However, the mean WTP estimate from DBDC - CV has lower standard errors than the WTP estimate from SBDC model.

Table 4: Mean WTP (in Ethiopian Birr ETB) per household per year for conservation of the H-GK forest from Single Bound Dichotomous Choice (SBDC) and Double Bound Dichotomous Choice (DBDC) Contingent Valuation (CV) models.

Models	Mean WTP	Standard error	P>|z|	[95% Conf. Interval]	
SBDC WTP	586.72	60.37	0.000	468.4	705.03
DBDC WTP	547.53	28.14	0.000	492.36	602.71

Note: The Purchase Power Parity (PPP)- corrected exchange rate on 31 December 2016, 1 USD=8.68 ETB).

Table 4 shows that the WTP estimates are ETB 587 and 547 from the SBDC from DBDC models respectively. The WTP estimate from the SBDC model has higher standard error

(lower efficiency) compared to the DBDC model. This is consistent with our expectation of efficiency gains of DBDC. The mean WTP estimates from both models fall within the same 95 percent confidence intervals. The estimated mean WTP value is about 2 percent of the average annual expenditure of sampled households, and this indicates that households have substantial demand for improving the protection of the H-GK forest and its biodiversity.

Different CV studies have showed that the WTP estimates for the same public good vary with the questionnaire formats; dichotomous choice steadily produced significantly higher estimates in comparison to open ended formats (Frykblom & Shogren, 2000). Respondents' strategic biases resulting from having incentives not to reveal their true WTP (Wertenbroch & Skiera, 2002), the degree of information provided (Hanley, *et al.*, 1995), framing (Green, *et al.*, 1998), reference point and anchoring (Bergman, *et al.*, 2010) and "yea" saying (Bateman, *et al.*, 2006) have been major concerns in designing CV surveys as design decisions will affect WTP estimates. 'Yea-saying' can occur in DC CV surveys when respondents tend to say 'yes' for the program; i) without seriously considering the costs (Nguyen, *et al.*, 2013), ii) in the desire to fulfil some accepted sense of social responsibility, and iii) an attempt to please the survey interviewers. To avoid "yea" saying, the respondents in this survey were reminded to consider their household budget and all other expenditures they had, when they are asked to respond to the DC questions. Johnston, *et al.* (2017) argue that stated preference questionnaire design should follow best practices applicable to all types of survey research to maximize the validity and reliability of values estimates. Validity refers to the minimization of bias in estimates, where reliability refers to minimization of variability (Bishop & Boyle, 2017). Our CV survey have sought to fulfill the recommendations for best practice stated preference surveys by (Johnston, *et al.*, 2017); including: i) Clear presentation of the baseline (or status quo) condition, and making the changes to be valued viewed as credible to the respondents. ii) Conducting pretesting and focus group discussions, iii) Survey designs making use of information from prior empirical research and thorough pretesting, iv) using the incentive compatible elicitation method of DC, and v)Providing a decision rule that is realistic and binding for the respondents (In terms of saying: "The conservation program will be implemented, and everyone will have to pay if the majority of people vote "yes" to paying the amount" and using a separate environmental tax as preferred

by respondents in the pilot survey). Thus, the CV survey was designed to minimize hypothetical bias, but we can of course not completely rule out that preferences stated in the survey do not represent respondents' "true" preferences for the forest conservation program in this survey.

4. Conclusion

This paper examined public environmental skepticism attitudes and tested whether it could predict the willingness to pay (WTP) for forest conservation. A Contingent Valuation (CV) survey was conducted to elicit WTP of households for improved forest conservation of in the H-GK forest in Northern Ethiopia, and avoiding the risk of bird and mammals species extinction. The result shows that high environmental skepticism such as believing that God causes climate change and that climate change discussions in the media are exaggerated reduce the likelihood of paying for forest conservation. Respondents that recognize the contribution of forests to mitigate climate change and those that prefer long-term consequences of adaptation measures to myopic present gains, on the contrary, have higher likelihood of being willing to pay. Therefore, improving awareness about forests and their biodiversity, what causes climate change, and reducing public environmental skepticism in general is likely to increase the WTP for forest conservation. As households with more education are more likely to pay for forest conservation programs, perhaps because of their higher awareness of the benefits of forest conservation to mitigate climate change, increasing the educational level can also be a measure to reduce environmental skepticism.

The DBDC CV survey seem to have worked well as the percentage of respondents accepting to pay the proposed bid decreased with increasing bid amounts, as expected. Proposed bid amount and payment modes influence respondents' decision to pay. Respondents are less likely to pay when the payment amount for forest conservation increases, and households who prefer to pay in labor time or in-kind mode are less likely to pay as the payment is specified in cash. This suggests that using appropriate payment modes for different groups of respondents will increase the overall WTP for forest conservation programs. Lastly, the estimated WTP values from the dichotomous choice models show that households have significant demand for the improving forests conservation.

Besides, the significant WTP estimates indicate the presence of potential financial resources from the local community to compensate ES providers in a PES scheme, and encourage them to use environmental friendly practices to boost environmental protection.

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Appendices

Table A-1 : Correlation matrix on socioeconomic characteristics and skepticism variables (obs=356)

	age	farm_size	Education	Expenditure	defor_aware	wildlife_awar	Forest_benft	God_causes	Exagg_discsn
Age	1.0000								
farm_size	0.4264	1.0000							
Education	-0.3822	-0.1648	1.0000						
Expenditure	0.1394	0.2329	-0.0867	1.0000					
defor_aware	0.0472	0.0586	0.0671	0.1343	1.0000				
wildlife_awar	0.1331	0.1772	0.0206	0.1477	0.4190	1.0000			
Forest_benft	-0.0878	0.0057	0.0469	0.2150	0.3246	0.1958	1.0000		
God_causes	0.0675	0.0604	-0.2069	0.1460	0.1256	0.0132	-0.0218	1.0000	
Exagg_discsn	-0.0261	0.0530	0.0615	0.0149	0.1206	0.1116	0.1775	-0.1846	1.0000

Figure A-1: Conditional expectation of density function for expenditure variable.

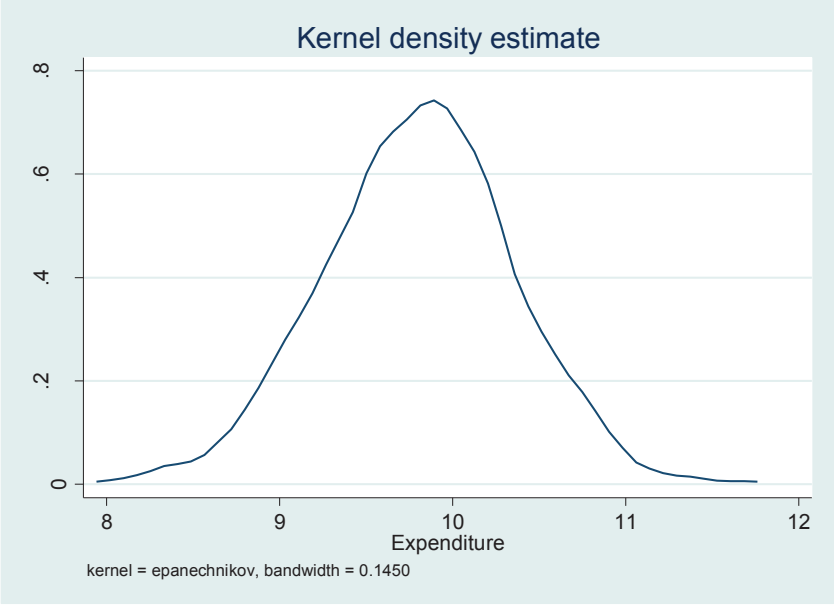

Table A-2: Results from Probit model and Interval data model regressions on socioeconomic factors (standard errors in Parenthesis)

	Probit Model b/se (Response=1)	Interval data b/se
Bid1	-0.003***	
	(0.00)	
Age	-0.020**	-6.486**
	(0.01)	(2.37)
Education	0.038	5.820
	(0.03)	(10.06)
Livestock	-0.020	-18.015
	(0.04)	(13.23)
Expenditure	0.099	47.690
	(0.16)	(54.77)
Farm size	0.110*	33.822*
	(0.05)	(16.75)
Household size	0.321	50.216
	(0.19)	(63.04)
Defor_aware	0.450*	167.608**
	(0.19)	(64.37)
Wildlife_aware	0.192	1.501
	(0.19)	(64.32)
Benft_forest	-0.362*	-40.782
	(0.18)	(59.63)
Labor_pay mode	-0.464**	-231.920***
	(0.17)	(60.65)
In-kind_pay	-0.992**	-228.338*
	(0.31)	(113.21)
Constant	0.140	-35.752
	(1.51)	(513.96)
Sigma Constant		429.777***
		(28.04)
AIC	365.0	911.4
BIC	415.3	961.7

*Notes: Significance levels. * p<0.1, ** p<0.05, *** p<0.01*

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Paper I discusses farmers' decision making behavior under hard uncertainty; and explores whether farmers aim to minimize loss, or minimize the maximum regret (opportunity loss) or maximize expected value, and if they use the same decision criterion consistently across different settings. An econometric analysis of field experiment data reveals that famers' use of decision criteria is not consistent. Most farmers use the criterion that minimizes loss when the value at stake is high; but with learning the farmers increase choices that minimize the maximum regret or maximum opportunity losses.

The rest of the papers employed stated preference methods. Paper II use a choice experiment to assess the nature of farmers' preference for river ecosystem services (ES) improvements. Results show farmers to have strong preferences for improving all river ES attributes, and strongest for those attributes that increase the provisioning ES of their agricultural yield. Farmers had highest willingness-to-pay for the flood protection service, and highest among farmers with larger plots closer to the river. The third paper employs a choice experiment to map farmers´ preferences for genetic trait of coffee varieties. Results show heterogeneous preferences, but in general farmers reveal stronger preferences for maintaining varieties with yield stability traits than for high yielding and early maturing traits. Thus, *ex situ* conservation for the latter traits is needed in order to preserve the large coffee genetic diversity in Ethiopia. The fourth paper examines how environmental skepticism attitudes affect farmers´ preferences for increased forest conservation in a contingent valuation survey. Results show high levels of environmental skepticism, such as believing that God causes climate change and that climate change discussions in the media are exaggerated, reduces farmers´ likelihood of paying for forest conservation.

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